# Forward

This document is the Fiscal Year 1996 Annual Performance Summary of the NASA-Ames Vertical Motion Simulation (VMS) Complex and the Crew Vehicle Systems Research Facility (CVSRF). It is intended to report to our customers and management on the more significant events of FY96. What follows are an Executive Summary with comments on future plans, the FY96 Schedule, a projection of simulations to be performed in FY97, performance summaries that report on the simulation investigations conducted during the year, and a summary of Simulation Technology Update Projects.
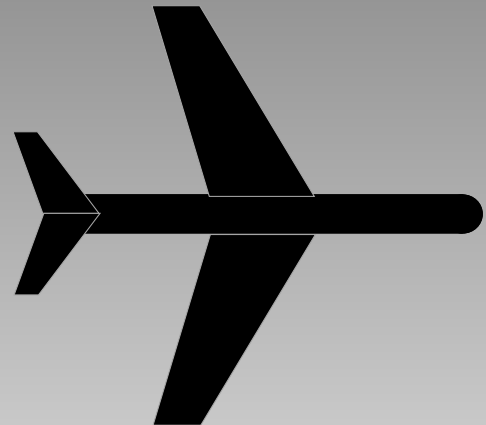
Aeronautical Test and Simulation Division
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1 February 1996

Acknowledgment

This Annual Report addresses the major accomplishments of the new and more encompassing flight simulation organization that resulted from the reorganization of FY94. The Ames Flight Simulation Facilities still consist of the Crew Vehicle Systems Research Facility (CVSRF) and the Vertical Motion Simulation Complex (VMS). Paramount to Ames operations has been the continuing commitment to uncommon excellence in the development and production of efficient, real-time, high fidelity, piloted flight simulations. The staff places very high value on customer relations and has successfully provided highly responsive, cost-effective, value-added support to all customers. We will continue to aggressively pursue and selectively invest in the enabling flight simulation and computational technologies to maintain our competitive edge and be second to no other flight simulation facility in the world.

The flight simulation laboratories, contained in two separate buildings at Ames Research Center, are part of the Aeronautical Test and Simulation Division organization. The CVSRF comprises of a Boeing 747-400 Flight Simulator, the Advanced Concepts Flight Simulator (ACFS), and an Air Traffic Control (ATC) simulator. The VMS Complex comprises of the Vertical Motion Simulator (VMS), four interchangeable cockpits (ICABs) and two fixed-base simulation labs. A brief description of these facilities follows this report in Appendix 1.

The purpose of this document is to briefly describe our accomplishments of the past year. Its outline includes this Executive Summary, Simulation Schedule for FY '96, Planned Projects for FY '97, VMS Simulation Projects, CVSRF Simulation Projects, and Technology Upgrades. The Simulation Projects sections contain simulation goals and high level discussions of results. Researchers and simulation engineers from industry and NASA are identified in the upper right hand corner and as part of the Investigative Team. The Technology Upgrades section describes projects completed or in process that will keep our simulation facilities state-of-the-art. Finally, a List of Acronyms was included for the reader's convenience.

Notable accomplishments for FY '96

There were 29 major simulation experiments conducted in the flight simulation laboratories in FY '96. These simulations reflect a continued concentration on NASA's focused programs such as High Speed Research (HSR), Advanced Subsonic Technology (AST), NASA's Space Operations, FAA/NASA Airspace Operations Systems, and other industry and government research issues.

All flight simulation experiments conducted at Ames support significant research that is responsive to the needs of the Nation with a focus on applied aeronautics research. Diversity, fidelity and breadth of flight simulation distinguish the research projects conducted at Ames as can be seen by reviewing the Simulation Projects Sections of this report

Technology Upgrade Projects

The Advanced Cockpit Flight Simulator began a major upgrade to its capabilities this year. Host computers and cockpit graphics systems were replaced by state-of-the-art systems which have substantially reduced operational cost with improved capabilities as well. In addition, the cab interior has been completely reconfigured to better represent future commercial airliners.

Both the 747-400 simulator and the ACFS received new advanced Vital VIII(i) Image Generation Systems. These full-color, day/night systems will significantly improve the ability of these simulators to support NASA research goals. In addition, work began to prepare for the future installation of 180 degree Image Presentation Systems in both cockpits.

The VMS Advanced Simulator Network (ASN) Project came to a successful close after several years of planning, engineering and implementation. This system, comprises of DEC Alpha Workstations and CAMAC I/O devices, which significantly reduce operational costs while attaining a ten fold increase in performance over the old hardware.

Design of a new interchangeable cab was completed this year and construction is well underway. This effort was in direct response to HSR and AST customer requirements for a transport cockpit that better supports their future research needs. It is anticipated that this ICAB will become operational during the summer of 1997.

Future Plans

All of the flight simulation facilities continue to be in high demand. There is a full list of projects for FY '97 that build on past research efforts and bring in new activities as well. We will continue our tradition of supporting mainstream NASA and national aeronautical development programs being second to none in state-of-the-art real-time flight simulation and enabling technologies. Automated tools for flight simulation and modeling, improvements in graphics and displays, and efficient computational environments are continuing efforts.

The new wide-field-of-view display system for the 747-400 simulator is expected to come on-line in December, 1996. The new system being installed on the ACFS will become operational during the 3rd Quarter of FY '97.

The activity, began last year, to make NASA flight simulation resources and research facilities more accessible will continue. Using concepts such as virtual reality and other modern techniques, demonstrations of a Virtual SimLab will be made. Next year will also see increased emphasis in interoperability between Ames facilities.

The new NASA organizational structure, i.e. that of "aerocentric" management and the implementation of Facility Groups will continue to be supported. In particular, the flight simulation laboratories will work with the Simulation Facility Group Director to develop a Strategic Management Plan to insure that the facilities are relevant, efficient, and cost effective.

FY96 Simulation Schedule

Simulation Operations Branch
Aeronautical Test and Simulation Division
Ames Research Center

Month/week headers: Oct '95 (29 16 23 30) | Nov '95 (6 13 20 27) | Dec '95 (4 11 18 25) | Jan '96 (1 8 15 22 29) | Feb '96 (5 12 19 26) | Mar '96 (4 11 18 25) | Apr '96 (1 8 15 22 29) | May '96 (6 13 20 27) | June '96 (3 10 17 24) | July '96 (1 8 15 22 29) | Aug '96 (5 12 19 26) | Sept '96 (29 16 23 30 7) | Oct '96 (14 21 28)

Simulation Facilities

VMS

Shift A:
- SLoad 2 — Army
- HSCT2 — NASA/Boeing McDD
- ASTOVL — NASA
- VMS Upgrade
- SSV — NASA-JSC Rockwell
- CTR6 — NASA FAA
- Slung Load 3 — Army
- HSCT3 — NASA/Boeing McDD
- ANOE4 — NASA
- SSV — NASA-JSC Rockwell
- VDTR — Sikorski

Shift B:
- SSV — NASA
- GTRS — NASA
- SIMFR — NASA
- HELMEE — Army
- SSV — NASA
- SIMFR — NASA

I-Cab Fixed Base
- CTR6
- SLoad
- ANOE/HELMEE
- VDTR

B747

Shift A:
- MultPar RW — FAA
- Upgrade
- JFK Loc — FAA
- PCA — NASA, Industry
- TRACON-FMS — NASA
- MultPar RW — FAA
- DARP — FAA
- CTAS DA — NASA
- TRACON-FMS — NASA
- AATT Data-Link — NASA

Shift B:
- Cert.
- Cert.
- Cert.
- Cert.
- Cert.

ACFS
- NCA 1
- 3D Audio

ATC

Aeronautical Test and Simulation Division   7

VMS Flight Simulation Projects

1. Slung Load 2   25 SEPT - 20 OCT
Aircraft type: CH47-Chinook
Purpose: To study cargo-class helicopter operations with an external load.

2. HSCT 2   23 OCT - 23 NOV
Aircraft type: High Speed Civil Transport
Purpose: To investigate handling qualities, control requirements and guidance concepts for this type of aircraft.

3. ASTOVL   4 DEC - 15 DEC
Aircraft type: Advanced Short Take off and
       Vertical Landing
Purpose: To evaluate the influence of the propulsion system and to demonstrate pilot/ vehicle interface options for the lift-fan (LF) configuration.

4. SSV   29 JAN - 8 MAR
Aircraft type: Space Shuttle orbiter
Purpose: To study the directional control handling qualities and other orbiter landing issues.

5. CTR 6   11 MAR - 11 APR
Aircraft type: Civil Tiltrotor
Purpose: To continue investigation of tiltrotor aircraft vertiport design, terminal area operations and certification issues.

6. GTRS   18 MAR - 31 MAR
Aircraft type: Civil tiltrotor
Purpose: To validate two generic tiltrotor simulation (GTRS) models for use in future tiltrotor simulations.

7. Slung Load 3   22 APR - 24 MAY
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To further study cargo-class helicopter operations with an external load.

8. HSCT 3   28 MAY - 29 JUN
Aircraft type: High Speed Civil Transport
Purpose: To investigate handling qualities, control requirements and guidance concepts for this type of aircraft.

9. ANOE 4   15 JUL - 2 AUG
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To continue development of the pilot-directed guidance (PDG) interface that includes active controls, a helmet mounted display, PDG system configuration, and PDG/Manual mode transition mechanics.

10. HELMEE   15 JUL - 2 AUG
Aircraft type: UH-60 Black Hawk helicopter
Purpose: To investigate the effectiveness of helicopter flight control system limiting and cueing.

11. SSV   5 AUG - 6 SEP
Aircraft type: Space Shuttle orbiter
Purpose: To study the directional control handling qualities and other orbiter landing issues.

12. VDTR   9 SEP - 18 OCT
Aircraft type: Variable Diameter Tiltrotor
Purpose: To quantify VDTR performance and handling qualities in terminal area operations.

VMS Technical Upgrades

1. ASN
Purpose: To upgrade the VMS host computer and Real Time Network with newer and higher performance systems.

2. SIMFR
Purpose: To improve simulation fidelity by evaluating and modifying the motion and visual cueing system performance.

CVSRF Flight Simulation Projects

1. MPA   16 OCT - 27 Oct
Purpose: To evaluate traffic handling capabilities and spacing requirements for running multiple parallel approaches (MPA) simultaneous instrument landing system (ILS) in instrument meteorological conditions (IMC).

2. NCA   11 DEC - 30 DEC
Purpose: To address both improved performance under engine only control and to attempt a blended control of all aircraft controls and engines concurrently.

3. JFK Locator   17 JAN - 26 JAN
Purpose: To acquire missed approach tracking data for use in determining the degree of safety and ease of landing operations conducted under instrument flight rules.

4. PCA   13 FEB - 23 FEB
Purpose: To investigate the robustness of the propulsion control aircraft (PCA) control laws by expanding the operational envelope over previous PCA experiments.

5. TRACON-FMS   11 MAR - 26 MAR
Purpose: To evaluate the precision of trajectories flown manually and with flight management system procedures, as compared to trajectories generated by the NASA Ames Research Center TRACON Automation System.

6. 3-D Audio   1 APR - 21 APR
Purpose: To evaluate use of spatiality sound techniques in detecting ground traffic while taxiing in terminal areas.

7. MPA   22 APR - 26 APR
Purpose: To evaluate traffic handling capabilities and spacing requirements for running multiple parallel approaches (MPA) simultaneous instrument landing system in instrument meteorological conditions.

8. DARP   10 MAY - 13 MAY
Purpose: To examine the viability of sending rerouted flight plan information to aircraft over the ocean by exploiting the capabilities of emerging satellite-based communications, enhanced avionics capabilities, and advanced ground-based air traffic control and dispatch systems.

9. CTAS/ FMS   13 JUN - 26 JUN
Purpose: To examine issues associated with automated air traffic control and its impact upon flight crews' ability to use aircraft automation.

10. BVNAV   10 JUL - 25 JUL
Purpose: To evaluate the use of lateral/ vertical navigation approaches using the Flight Management System.

11. AATT   16 SEP - 1 OCT
Purpose: To evaluate the alert and protected zone airspace definitions for free flight, and to investigate pilots' interpretation of Visual Flight Rules (VFR) right of way procedures and their application to the free flight environment.

CVSRF Technical Upgrades

1. FANS Upgrade
Purpose: To study issues related to incorporating an advanced avionics system upgrade to the 747-400 simulator.

2. ACFS Upgrade Phase 2
Purpose: To ensure the simulator remains capable of supporting mission critical research in the areas of human factors and aviation safety for NASA.

FY97 VMS Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Variable Diameter Tiltrotor (VDTR)	DoD	Sikorsky	Quantify VDTR performance and handling qualities in terminal area operations.
High Speed Civil Transport	HSR	McDonnell Douglas, Boeing NASA Ames	Investigate handling qualities, control requirements and guidance concepts for this type of aircraft.
Advanced Short TakeOff and Vertical Landing (ASTOVL)	DoD	Boeing, Lockheed Martin, NASA Ames	Evaluate the influence of the propulsion system and to demonstrate pilot/ vehicle interface options for the lift-fan (LF) configuration.
Simulation Fidelity Requirement	Other	Lockheed Martin, NASA Ames	Improve simulation fidelity by evaluating and modifying the motion and visual cueing system performance.
Space Shuttle	Space Ops	Rockwell, Honeywell, JSC	Study the directional control handling qualities and other orbiter landing issues.
Helmet Mounted Display (HMD)	DoD	NASA Ames, U.S. Army	Evaluate the helmet mounted display system using the pilot's ambient vision.
Slung Load	DoD	Boeing, NASA Ames, U.S. Army	Study cargo-class helicopter operations in a degraded visual environment with an external load.
Partial Authority	DRA	NASA Ames, U.S. Army	Apply the Partial Authority SCAS (PAS) concept to the AH—64 Apache.
Comanche	FAA	NASA Ames	Provide an assessment to support cost benefit trade-offs resolving potential shortcomings on ACFS per-formance.

FY97 CVSRF Simulation Projects

PROJECT	PROGRAM SUPPORTED	CUSTOMERS	TEST OBJECTIVES
Taxiway Navigation & Situation Awareness (T-NASA)	TAP/LVLASO (ACFS)	NASA Flight Management	Improve aircraft movement on the airport surface through use of a Head Up Display (HUD), Moving Map, and 3D Audio cues
CTAS/FMS Data-link	AATT (ACFS)	NASA Flight Management, FAA	Investigate pilot performance utilizing automatic data-link of CTAS approaches into on-board Flight Management Computers (FMS)
Neuro Controlled Aircraft (NCA) Propulsion Controlled Aircraft (PCA)	PCA (ACFS, 747–400)	NASA Ames, NASA Dryden, McDonnell Douglas	Evaluate use of fly-by-throttle control laws, neural nets and fuzzy logic to control transport aircraft during major control failures.
Tactical Decision Making Study (TDMS)	AATT (ATC)	NASA Flight Management, FAA	Evaluate workload issues for Free-Flight and the transition from an overloaded Free-Flight environment to a ground controlled environment.
Converging Approaches	FAA (747–400)	FAA Headquarters	Evaluate cockpit issues when conducting missed approaches, particularly when using the FMS in a converging runways environment.
TRACON-FMS Trajectory Synthesis (TFTS) II	TAP (747–400)	NASA Flight Management	Evaluate the alert and protected zone airspace definitions envisioned for "free flight."
Free Flight	AATT (747–400)	NASA Flight Management	Evaluate human factors issues associated with the use of automated air-ground communications in high density terminal area operations
Multiple Parallel Approaches	FAA (747–400)	FAA Technical Center	Evaluate traffic handling capabilities and spacing requirements for running multiple simultaneous parallel approach operations.
CTAS-FANS Integration	TAP (747–400)	NASA Flight Management	Evaluate issues pertaining to the transmission of optimized descent advisories utilizing FANS capabilities.
Reduced Spacing Operations	AATT (747–400)	NASA Flight Management	Evaluate human factors issues utilizing reduced runway separation distances. This study will focus on issues pertaining to wake vortex and flight management system utilization.
Obstacle Free Zone	FAA (747–400)	FAA Aeronautical Center (Oklahoma City)	Evaluate the human factors issues associated with conducting emergency missed approaches below minimums.
Complex Air-Ground Comm.	AATT (747–400)	NASA Flight Management	Evaluate human factors issues associated with the use of automated air-ground communications in high density terminal area operations.
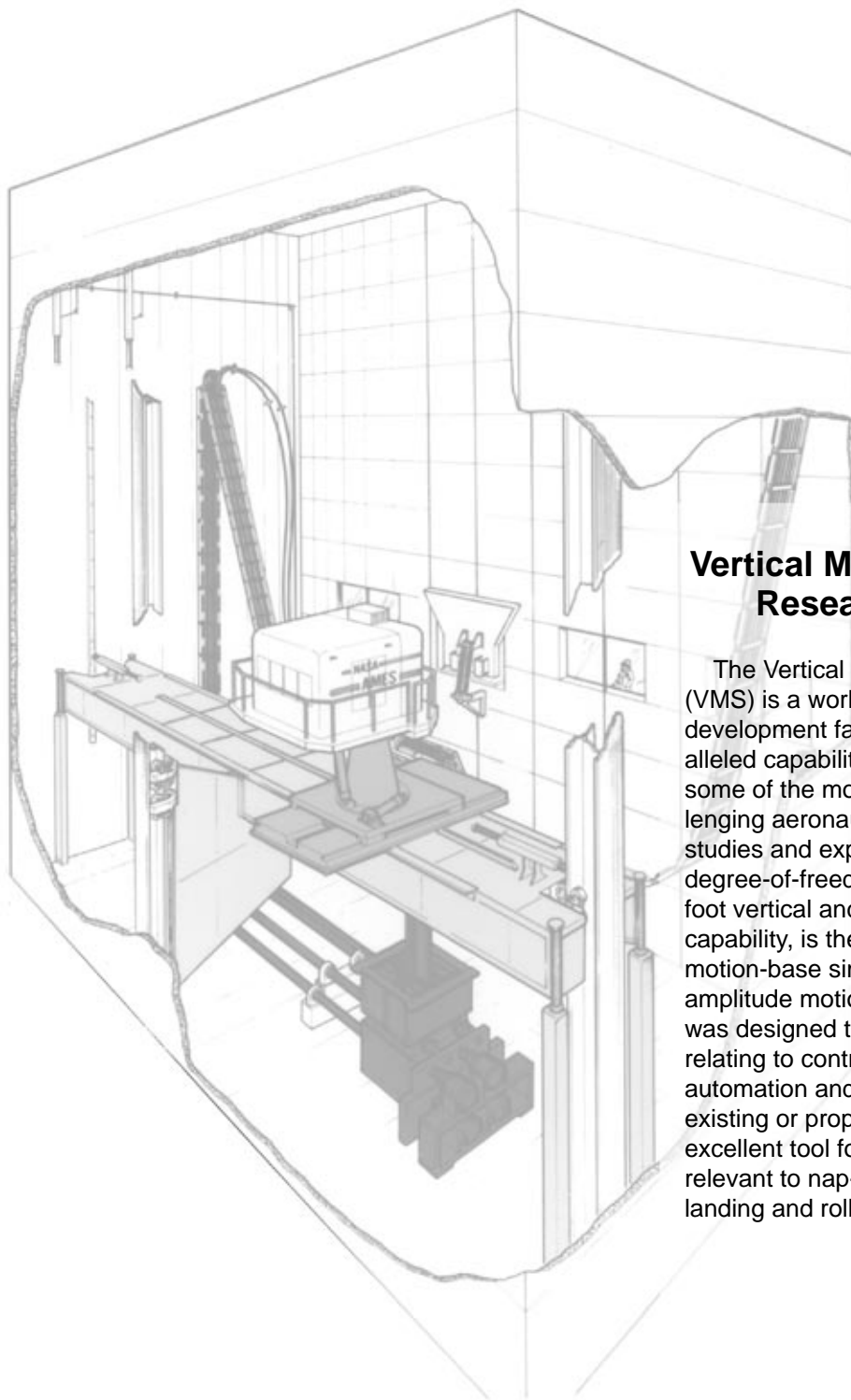
Vertical Motion Simulator Research Facility

The Vertical Motion Simulator (VMS) is a world-class research and development facility that offers unparalleled capabilities for conducting some of the most exciting and challenging aeronautics and aerospace studies and experiments. The six-degree-of-freedom VMS, with its 60-foot vertical and 40-foot lateral motion capability, is the world's largest motion-base simulator. The large amplitude motion system of the VMS was designed to aid in research issues relating to controls, guidance, displays, automation and handling qualitites of existing or proposed aircraft. It is an excellent tool for investigating issues relevant to nap-of-the-earth flight, and landing and rollout studies.

Slung Load 2

Joe DeMaio, U.S. Army ATCOM
Duc Tran, NASA ARC; Luong Nguyen, Syre/ Logicon

Summary

A piloted simulation experiment was performed by the U.S. Army Aeroflightdynamics Directorate to study helicopter operations in a degraded visual environment (DVE) with an external load. The primary objective was to document how different stability and control systems (SCAS) interact with the external load during mission-related maneuvering.

Introduction

In 1993, the U.S. Army Aviation and Troop Command (ATCOM) and Boeing Defense & Space Group, Helicopters Division undertook a multi-year cooperative research and development agreement to develop data that could be used to augment the handling quality specifications for military helicopters with requirements tailored for the cargo mission, including external load and DVE operations. Additional objectives were (1) resolve the simulation fidelity issues that were raised during the Slung Load 1 simulation, (2) investigate directional axis bandwidth requirements for cargo helicopters in a DVE including external load operations, (3) investigate the effects of reduced thrust margin on the ability to perform cargo mission maneuvers, and (4) investigate the effects of flying cargo-class helicopters with several types of stability and control systems with an external load.

Related research included developing additional maneuvers for the cargo role and external operations, investigating the effects of reductions in the thrust margin and changes in the stability and control systems have on the handling qualities of military helicopters.

Simulation Results

Experimental results show significant changes (from Slung Load 1) accomplished for this simulation:

• Additions and modifications were made to the tandem-rotor CH-47 helicopter math model. These mainly affected the SCAS , load dynamics and engine-torque response of the vehicle.

• Cockpit hardware changes included modified cyclic and collective grips. Also, lighting for the instrument panel was changed to be compatible with the night vision goggles used to simulate DVE tasks.

• The computer generated imagery was improved by adding scaled objects to provide better lateral and height visual cueing to the pilot.

• Enhanced aural cueing was achieved by adding drive-train loading sounds.

• An additional "task page" display was implemented for the 'hover-turn' task.

With all the above changes completed, researchers conducted one week of fixed base operations in the ICAB facility to verify the model, to fine tune the control system and to setup the task configurations. They then performed four weeks of motion based simulation.

Investigative Team

U.S. Army Aeroflightdynamics Directorate
Airworthiness Qualification & Test Directorate
Boeing Defense & Space Group,
  Helicopter Division
R. Heffley Engineering
Hoh Aeronautics Inc
NASA Ames Research Center
Naval Air Test Center

To address the objective, the baseline math model has been configured as a CH-47D Chinook, the U.S. Army's primary cargo helicopter.

High Speed Civil Transport 2

Dan Dorr, Joe Conley, NASA ARC
Chris Sweeney, Robert Morrison, Syre/ Logicon

Summary

This piloted VMS study consisted of two integrated experiments: (1) Collect piloted evaluations to support the selection of a preliminary terminal area control concept for the High Speed Civil Transport. (2) Evaluate the unaugmented airplane in the terminal area for the Ref. H assessment task.

Introduction

The High Speed Civil Transport 2 (HSCT 2) experiment was a continuation of a collaborative effort between NASA Ames Research Center, McDonnell Douglas Aircraft (MDA), and Boeing Aircraft Company (BAC). The HSCT will allow airlines to provide profitable, Mach 2.2 -or -better intercontinental service to more than 300 passengers near 2006. It will also use standard fuel and be equipped with superefficient combustors for reduced nitric oxide emmissions and low-noise nozzles. This experiment's objectives were:

• Collect piloted evaluations to support the selec-tion of a preliminary terminal area flight control system (FCS) concept for the HSCT, and

• Evaluate the unaugmented airplane in the terminal area for the Reference H - Cycle 2B (Ref. 1) assessment task.

Simulation Results

The pilots evaluated four task-configuration combinations while using each of three HSCT longitu-dinal flight control laws: the MDA Alpha command, the MDA Theta command and the BAC Gamma dot V command. Lateral/directional control was provided by the MDA FCS. The task-configurations were:

Presently, the HSCT exists on paper only. Its appearance will be similar to this model that is approaching San Francisco International Airport.

The Head-Up Display design was used in this experiment. Although, no guidance cue (symbology) was used.

• Sidestep approach and landing with moderate turbulence, medium aircraft weight, aft c.g., and various actuator limits

• Go-around with moderate turbulence, medium aircraft weight, aft c.g., and various actuator limits

• Acoustic profile climb from runway with moderate turbulence, heavy aircraft weight, and forward c.g.

• Approach and landing with wind shear, medium aircraft weight, and aft c.g.

As a preliminary result, the three competing longitudinal control laws were down selected to only two: the BAC Gamma dot V and MDA Alpha com-mands.

The researchers expressed their utmost satisfac-tion and appreciation with SimLab's efforts in devel-oping the simulation, which included implementing the latest BAC math model for HSCT, on an ex-tremely tight schedule.

Investigative Team

Boeing Aircraft Company
Hoh Aeronautics
Honeywell
McDonnell Douglas Aircraft Corp.
NASA Ames Research Center

Advanced Short TakeOff and Vertical Landing - Lift Fan

James Franklin, NASA ARC
Leighton Quon, Joseph Ogwell, Syre / Logicon

Summary

Piloted simulations were usd to evaluate design guidelines and to assess the merits of contending design approaches. Primary objectives were: (1) Determine the influence of the propulsion system. (2) Evaluate the pilot/ vehicle interface. (3) Assess flying qualities for designated operational tasks.

Introduction

NASA Ames Research Center is participating in technology development for advanced short takeoff and vertical landing (ASTOVL) fighter aircraft. Integration of flight and propulsion controls is one of the critical technologies being pursued in this program. Specifically, NASA will carry out design guideline analyses for the control system and conduct piloted simulations on the VMS to evaluate design guidelines and to assess the merits of contending design approaches.

Using a generalized simulation model, a moving-base simulation of a lift-fan short takeoff/vertical landing supersonic fighter aircraft was conducted on the VMS. The primary objectives of the experiment were: (1) Determine the influence of the propulsion system. This includes integration of lift fan/core/ aerodynamic controls; pitch/heave dynamic design variations such as force/moment coupling due to fan/ core thrust and fan/core response due to inlet guide vane authority /acceleration limits. (2) Demonstrate and evaluate the pilot-vehicle interface as pitch/ heave control blending in transition and hover; control mode switching compatibility, pitch control force gradients for hover; Direct Lift Control to improve handling in turbulence; fighter compatible Heads-Up Display (HUD) for Approach and Hover modes; and HUD symbology for hover point acquisition. (3) Demonstrate and assess the flying qualities for operational tasks such as airfield and shipboard takeoff and landing, instrument meteorological conditions operations, and winds /turbulence /sea states.

Simulation Results

The VMS operations ran for two weeks. Ten pilots flew over 400 data runs to evaluate the flying quali- ties of the aircraft in cruise, transition, and hover modes. In addition, flight test engineers from Boeing, Lockheed, Naval Air Test Center and Royal Air Force flew familiarization runs. Jack Franklin summarized the results by stating that although this simulation was the first effort by the government to evaluate the lift fan performance criteria for the ASTOVL, the preliminary data shows a consistent lift fan and core engine response characteristics requirements to meet desirable handling qualities in a shipboard landing task. Also, the roll control power required to maintain the station point capture exceeds the MIL-F-83300 specification. For most approach and station keeping point acquisition tasks, Level I handling qualities were achieved.

Investigative Team

Royal Air Force
U.S. Air Force
Boeing Aircraft Company
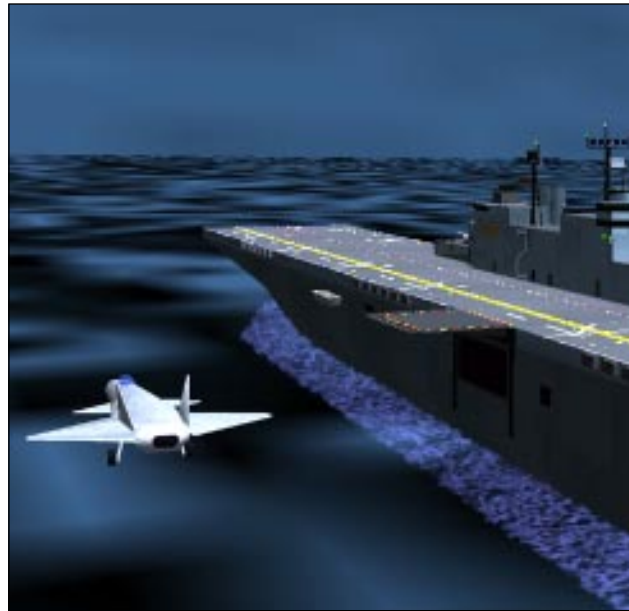
The ASTOVL lift fan aircraft configuration is represented above. A task performed in this simulation was to touchdown within 5 ft. radius of pad center.

Lockheed Martin
NASA Ames Research Center

Space Shuttle Vehicle

Howard Law, NASA JSC
Robert Gardner, NASA ARC; Chris Sweeney, Syre / Logicon

Summary

The Shuttle orbiter landing and rollout studies are an ongoing part of the Space Program. Every six months simulations are performed at the VMS to fine-tune the Shuttle orbiter's landing systems. The major goal of this simulation was to study a proposed expansion of the head and tail wind limits. The simulation results will help determine whether the handling qualities of the orbiter are acceptable with large head and tail winds.

Introduction

The Space Shuttle Vehicle (SSV) orbiter model has been simulated at the VMS complex since the late 1970s. The basic model has evolved and matured in the intervening years. The simulation at Ames has been used to test flight control improvements, safety features, head-up display development, proposed flight rule modifications, and model changes. The simulation is also used for training astronauts using realistic landing and roll out scenarios, including some cases with system failures. Primary objectives were:

• Evaluate the orbiter handling qualities in headwinds of up to thirty-five knots and tailwinds of up to twenty-five knots to determine the launch flight rule head and tail wind limits. The desire is to have unlimited head and tail winds as long as no system limits are exceeded.

• Run upcoming crews and astronaut candidates through a crew familiarization matrix.

Simulation Results

All simulation objectives were met. Data was collected for 1739 runs flown by thirty-four pilots and astronauts.

During the engineering phase of the simulation, the testing procedure consisted of the pilot landing the orbiter given various configurations and initial conditions based on cases defined in engineering matrices. Data of primary importance to each matrix (e.g. maximum head/tail and crosswind magnitude) was immediately recorded by the researchers. Some of the matrices required the pilot to give handling qualities ratings based on the Cooper-Harper scale.

The orbiter model used in this simulation was the baseline model used previously at the VMS complex with model options and improvements specific to this simulation.

Preliminary results indicate that the head wind limit of twenty-five knots and the tail wind limit of fifteen knots should remain at those values.

During the crew familiarization phase of the simulation, various atmospheric and failure conditions were presented to the pilot, including a variety of winds, tire failures, chute deployment speeds, lake bed/concrete runways, wind gusts, night scenes, and TransAtlantic Landing runways. The runways used included Kennedey Space Center (KSC) 15, KSC 33, Edward's 15, Edward's 22, Edward's 23, Banjul, Moron, Zaragoza, and Ben Guerir. The crew familiarization session reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase.

Investigative Team

NASA Ames Research Center
NASA Johnson Space Center
Rockwell International
Rockwell Space Operations Company

Generic Tiltrotor Simulation

William Decker, NASA ARC
Duc Tran, NASA ARC; Steven Belsley, Syre / Logicon

Summary

The purpose of this program was to validate two tiltrotor models for the first time, using pilot-in-the-loop simulation. The first model, the Generic Tiltrotor Simulation (GTRS) CTR-4/95 Rev. C, represents the NASA configuration of a thirty-nine passenger transport tiltrotor. The second, Preliminary Design Generic Tiltrotor Simulation (PDGTRS) is a simplified version of the above GTRS model with all the propri-etary portions of the model generalized.

Introduction

The GTRS version will support future simulations of the NASA configuration and of other aircraft modeled with specific/proprietary wind tunnel data. The PDGTRS version will be used for simulation efforts earlier in the design cycle; before much time and effort is expended in the collection of wind tunnel data. Also, the PDGTRS model can be utilized by industry and academia due to its nonproprietary nature. Primary objectives were to:

• Validate the CTR-4/95 Rev. C configuration with a pilot in the loop,

• Evaluate CTR-4/95 performance and handling qualities with respect to the Bell XV-15 tiltrotor configuration,

• Identify and correct deficiencies by flying the model through the complete flight envelope, and

• Validate the PDGTRS model with a pilot in the loop.

NASA created a non-proprietary preliminary design version of GTRS called PDGTRS. This model is based on the Short Haul Civil Tiltrotor Baseline .

Simulation Results

All the simulation objectives were met in a two week session in the VMS.   The first week was focused on validating the GTRS CTR-4/95 Rev. C model and comparing it to the Bell XV-15 tiltrotor configuration for the planned flight regimes. The PDGTRS model was verified and validated in the second week.   Handling quality characteristics and flight profile evaluations were conducted by NASA Ames and Bell Helicopter Textron (BHT) XV-15 pilots during both sessions.

All models were successfully validated and deemed ready for future simulation use. According to BHT's chief pilot, R. Erhart, "the XV-15 configuration flew like an XV-15." He also stated that the CTR-4/95 version flew very well and required minimal tuning to meet the desired initial performance goals. The PDGTRS model will be used as the baseline for Sikorsky's Variable Diameter Tiltrotor (VDTR) simula-tion reported on page 25.

Investigative Team

Bell Helicopter
EMA Rotorcraft / Aerodynamic Analysis
NASA Ames Research Center
Sikorsky Aircraft

The VMS computer generated images are state-of-the-art. An out-the-window display shows the San Francisco Bay area during an approach.

Civil Tiltrotor 6

William Decker, NASA ARC
Leighton Quon, Joe Ogwell, Syre / Logicon

Summary

This piloted VMS simulation addressed noise-abatement issues such as introducing a commercial tiltrotor transport into urban areas where vertiports are conveniently located while under the minimum noise requirement, and designing candidate noise-abatement approach profiles. The primary objective was to conduct handling qualities evaluations of candidate low-noise procedures and guidance to determine their suitability for routine commercial flight operations.

Introduction

The CTR-series of simulation experiments have investigated certification and terminal area operations issues for a civil tiltrotor (CTR) transport. Early experiments focused on near-term FAA certification requirements. More recent work retained emphasis on flight safety, but began addressing aircraft and transportation system design issues, particularly those dealing with engine contingency power and consequent vertiport size requirements. For locating vertiport sites near congested urban areas, aircraft noise is an important factor in obtaining community acceptance. NASA's Short Haul Civil Tiltrotor (SHCT) program is currently investigating noise abatement strategies. Airframe design, especially rotor design, and terminal area operating profiles can provide the primary solutions to noise reduction for a tiltrotor. The CTR-6 handling qualities experiment focused on potential noise abatement operating profiles and their impact on pilot workload during the critical approach and landing phase. Primary objectives were:

• Investigate approach procedures for noise abatement.

• Develop vertical flight path and speed profiles based on input from recent and previous XV-15 approach flight condition noise tests.

• Adapt lateral (horizontal plane) flight path guidance developed at Ames for advanced jet-lift STOVL aircraft. (A refined version of the Civil Tiltrotor Transport primary flight display format introduced during the CTR-5 experiment was used for primary instrument guidance.)

• Perform handling qualities evaluations for alternative approach profiles.

• Provide time history records from this experiment to NASA acoustics researchers to predict the noise impact (ground footprint) for the different procedures.

Simulation Results

The planned objectives of the simulation were successfully met. A total of 294 data runs were completed by eleven pilots from the following organizations: NASA-Ames, Bell Helicopter, McDonnell Douglas Helicopter Systems, Sikorsky Helicopters, Boeing Helicopters, FAA Headquarters, FAA Rotorcraft Directorate and British CAA.

CTR-series vertical and speed profile guidance was successfully merged with the horizontal guidance developed by Ames' VSRA (STOVL) flight program. The combined guidance provided effective terminal area approach profiles for reducing noise levels.

Handling qualities were generally satisfactory and desired performance was achieved. However, display and guidance issues such as a need for "implicit" airspeed cueing at slow speeds need to be addressed.

While further iterations of approach profile designs are warranted, the CTR-6 experiment has provided a solid foundation for the establishment of complex instrument approach noise abatement profiles.

Investigative Team

U.S. Air Force	Bell Helicopter
Boeing Aircraft Company	Civil Aviation
FAA HQ	McDonnell Douglas
NASA ARC	Sikorsky Helicopter
UC, Davis	

Civil tiltrotor (CTR) on short final to San Francisco vertiport.

Slung Load 3

Joseph DeMaio, U.S. Army ATCOM
Luong Nguyen, Syre/ Logicon

Summary

A piloted simulation experiment was performed by the U.S. Army Aeroflightdynamics Directorate to study helicopter operations in a degraded visual environment (DVE) with an external load. The primary objective was to document how different stability and control systems interact with the external load during mission-related maneuvering.

To address the objective, the baseline math model was configured as a CH-47D Chinook, the U.S. Army's primary cargo helicopter.

Introduction

In 1993, the U.S. Army Aviation and Troop Command and Boeing Defense & Space Group, Helicopters Division undertook a multi-year cooperative research and development agreement to develop data that could be used to augment the handling quality specifications for military helicopters with requirements tailored for the cargo mission, including external and DVE operations. Specific objectives were:

• Develop an understanding of control system bandwidth criteria when the slung load causes two regions of apparent closed loop capability.

• Investigate the possibility of using a limited authority stability and control augmentation system (SCAS) to achieve attitude command, attitude hold benefits.

• Investigate the effect of yaw axis command bandwidth.

• Evaluate the fidelity of three software models of the external load.

Simulation Results

All of the specific objectives were addressed. Pilots from the Army, NASA and Boeing flew 847 data runs, which included a variety of low-altitude, low-speed precision flight tasks.

The existing control system bandwidth criterion was found to be equally valid for helicopters with and without external loads. The three limited authority SCAS configurations showed varying levels of success for the four flight maneuvers flown. Results indicated good potential for a well-tailored 10% authority SCAS. The necessity for a significant yaw bandwidth requirement and the definition of an appropriate task need further investigation.

The three external load software models implemented were: a single-point and a dual-point suspension load model developed at Ames, and a dual-point one developed by Boeing. The single-point model was used for a majority of the experiment.

The VMS motion system was found to be particularly beneficial in evaluating "load-on" handling qualities by providing the subtle, uncommanded motion cues that resulted from external load oscillations.

Investigative Team

U.S. Army Aeroflightdynamics Directorate
Airworthiness Qualification and Test Directorate
Boeing Defense & Space Group,
  Helicopter Division
NASA Ames Research Center
Hoh Aeronautics Inc.
R. Heffley Engineering
Naval Air Test Center

The tasks include precision hover maneuvers between pylon markers and out to 60 kts.

High Speed Civil Transport 3

Dan Dorr, Joseph Conley, NASA ARC
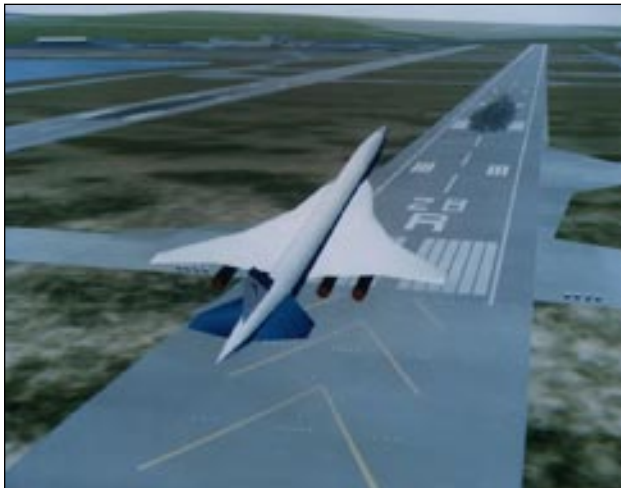**Chris Sweeney, Robert Morrison, Syre/ Logicon**

Summary

This piloted VMS study consisted of two integrated experiments: (1) Pilot evaluations of the angle-of-attack and gamma-V response types were conducted for final longitudinal control law downselect. (2) Control Sizing Criteria was designed to fully define the requirements necessary for pitch recovery, go-around, crosswind landing and offset landing.

Introduction

A whole new generation of passenger aircraft, the High-Speed Civil Transport (HSCT) is seen as significantly boosting the U.S. aeronautics industry's competitiveness. In 1990, NASA's High-Speed Research (HSR) Program was initiated to develop and verify, in cooperation with the U.S. aeronautics industry, the high-leverage technologies essential for an environmentally acceptable, economically viable HSCT capable of carrying 300 passengers at Mach 2.2-or-better by the year 2006. NASA's HSR is intended to help take U.S. firms well beyond the technical level of British Aerospace and Aerospatiale of France, joint buiders of the Concorde.

HSR's Guidance and Flight Controls (GFC) team is conducting a series of simulation and flight test experiments as part of a coordinated research and technology development effort designed to validate guidelines and methods to meet the flying qualities and certification criteria that will support a High-Speed Civil Transport airplane development program. One primary objective for the GFC team is to develop and validate integrated controls system concepts and design methods.

A primary objective is to develop and validate integrated control system concepts and design methods consisting of guidance, control, and display laws.

The VMS has run six simulation sessions since 1993. The simulations have been used to research flight control systems, guidance algorithms, HUD development, and aircraft configurations. The Ref H-Cycle IIb version of the Boeing basic airframe model has been used and evolving since 1993. Primary objectives were:

• Collect data for the longitudinal control law downselect decision between the Boeing Gamma dot V system and the McDonnell Douglas Alpha system and compare these results with those gathered on the Total In-Flight Simulator (TIFS) at CALSPAN.

• Conduct controls sizing criteria tasks to aid the decision on the size for the horizontal tail's elevators and stabilizers.

Simulation Results

The Boeing Gamma dot V longitudinal control system was selected as the longitudinal control system for the aircraft and the Control Sizing Criteria tasks were designed to narrow the tasks and criteria for sizing the tail of the aircraft.

Investigative Team

Boeing Aircraft Company
Honeywell
McDonnell Douglas Aircraft Corp.
NASA Ames Research Center

Results of two simulator tests were compared to determine the flight control system used in this new aircraft.

Advanced Nap-of-the-Earth 4

Richard A. Coppenbarger, NASA ARC
Duc Tran, NASA ARC; Luong Nguyen, Syre / Logicon

Summary
The ANOE simulation studied the capabilities of a rotorcraft with an automated Pilot-Directed-Guidance (PDG) system. The PDG system relied on *forward-looking sensor information* and *digital terrain elevation data* to perform automated terrain-following and speed control. The fundamental objective was to improve the pilot-interface of the PDG system by evaluating various mechanisms of cueing the pilot in preparation for automated obstacle avoidance maneuvering.

Introduction
Pilots flying rotorcraft close to the ground in nap-of-the-earth (NOE) flight are confronted with unique guidance and control tasks that require a high degree of skill and concentration. NOE flight tasks, which can be intensified by low visibility and high auxiliary workload conditions, include long-range mission planning as well as ground and obstacle avoidance. Although most commonly associated with military missions, workload intensive flight regimes requiring continuous situational awareness are also encountered by civilian rotorcraft pilots involved with Emergency Medical Service and the fire fighting operations.

With the Pilot-Directed Guidance system, the pilot is able to continuously control the flight-path of the vehicle while relying upon an inner-loop guidance and control system to perform automated obstacle detection and avoidance maneuvering, terrain clearance altitude tracking, and inertial velocity hold. An important characteristic of PDG, in comparison to previously considered automated NOE concepts, is that it requires pilot interaction and does not allow the vehicle to be flown in the absence of pilot input. Following the results from an initial fixed-base simulation evaluation of the PDG obstacle avoidance system, the PDG pilot interface was modified to allow direct pilot override of the automatic controls.

The new PDG system provides for true obstacle avoidance protection along the inertial velocity vector of the vehicle. Automated control inputs are used to back-drive the collective and cyclic control stick positions. The final collective and cyclic positions, however, are controllable through pilot inputs that overide the control forces from the PDG. It is the final pilot-determined position of the cockpit control inceptors (cyclic, pedals, and collective) that are input to the vehicle dynamics. Simulation objectives were:

Obstacle avoidance guidance in the Pilot-Directed-Guidance system uses forward-looking sensors. The radar sensors used in this simulation have a range of 1,000 ft, a field view of 50 X 25 degrees, and sweep rate of 1 second.

(1) Continue the development of the PDG pilot interface that includes active control implementation, Head Up Display symbology, PDG system configuration parameters, and PDG/ Manual mode transition mechanics. (2) Explore pilot-workload and system performance issues for PDG missions under a variety of environmental and mission dependent conditions. (3) Experiment with the secondary task which required heads-down visual attention that will be sensitive to the differing levels of demand associated with the test conditions of the primary flight task.

Simulation Results
All major objectives of the simulation were addressed. Preliminary results suggest that pilot's preferred the use of active back-driven control inceptors when operation with PDG. Turning off the obstacle-avoidance protection was only acceptable under good visibility conditions. The simulation has helped identify future research focus areas. The guidance and guidance-related symbology will be improved to reduce maneuver indecisiveness and produce smoother guidance trajectory solutions. Improvements to the controller to reduce lateral/vertical dynamic coupling in the model will also be an area of future work.

Investigative Team
NASA Ames Research Center
Stirling Dynamics, Inc.

Helicopter Maneuver Envelope Enhancement 4

Matthew Whalley, U.S. Army ATCOM
Chuck Perry, Syre / Logicon

Summary

A piloted simulation study was performed by the U.S. Army Aeroflightdynamics Directorate to develop insight into the issues associated with using a predictive polynomial neural network (PNN) in conjunction with a collective force-feel system to provide tactile feedback to the pilot regarding torque output relative to the maximum continuous limit.

Introduction

Helicopters typically contain complicated flight envelope limits which are difficult to predict and poorly annunciated to the pilot. Violation of such limits can occur as a result of flight conditions or maneuver states that are difficult for the pilot to remain fully aware of or plan for. Therefore, to enhance the safety and exploit the full potential of fly-by-wire helicopters, it is appropriate that methods for providing control margin cues and flight envelope cues be developed. The primary objective was to investigate the performance of the polynomial neural network for predicting collective position corresponding to maximum continuous torque.

The Helicopter Maneuver Envelope Enhancement (HelMEE) 4 experiment was designed to further explore helicopter limiting and cueing as a follow-on to HelMEE 2 and 3. Specifically, HelMEE 4 investigated the use of a polynomial neural network to predict the collective position corresponding to maximum continuous rotor torque. The predicted collective position was cued to the pilot in order to reduce or eliminate the need for visually monitoring the torque gauge during a task. Six cue configurations, consisting of combinations of breakout force, force gradient and stick shaker were applied to the collective stick at the predicted position to allow the pilot to feel the location of maximum continuous torque.

Data was also collected in various aircraft configurations with and without the PNN cueing turned on. NASA test pilots as well as pilots from the Army, Navy, Sikorsky, and Boeing participated in the simulation.

Simulation Results

Preliminary data analysis showed that, of the six different cue configurations tested, the best results were obtained with the configuration that had PNN prediction with a collective breakout/gradient and stick shaker. The collective breakout/gradient began at the predicted location for maximum continuous torque (80%) with the stick shaker activated at 90% torque. The PNN worked best with a Horizon Time of twenty frames (0.5 seconds into the future).

The HelMEE simulation (and the ANOE simulation that ran during the same period) were significant in that they were the first production simulations to use the new VMS SimLab configuration. This included a DEC Alpha host computer, a CAMAC industry standard input/output system and a Heads-Up Display/Computer Generator Image (HUD/CGI) mix on the center monitor of the cab visual system which replaced the traditional HUD or Integrated Helmet And Display Sighting Systems. All project objectives were met, and 962 data runs were collected.

Investigative Team

U.S. Army Aeroflightdynamics Directorate
Boeing Defense & Space Group,
  Helicopter Division
NASA Ames Research Center
Sikorsky Aircraft

For this experiment, the UH-60A was used as the helicopter math model.

Space Shuttle Vehicle

Howard Law, NASA ARC
Chris Sweeney, Estela Hernandez, Leslie Ringo, Syre / Logicon

Summary

The Space Shuttle orbiter landing and rollout studies are performed at the VMS to fine-tune the Shuttle orbiter's landing systems. The major goal of this simulation was to study tire failure scenarios emphasizing the selection of either the Lake bed runway or the concrete runway. The simulation results will help determine which runway to select based on different tire failure scenarios.

Introduction

The Space Shuttle Orbiter model has been simulated at SimLab since the late 1970s. The basic model has evolved and matured in the intervening years. The simulation at Ames has been used to test flight control improvements, safety features, HUD development, proposed flight rule modifications, and model changes. The simulation is also used to give astronauts realistic landing and roll out scenarios, including some scenarios with system failures, before their flight. The guidance and controls include the latest modifications (OI-24).

Simulation objectives were:

1) Evaluate the landing surface (concrete or lakebed) best suited to landing the orbiter with a failed tire. Evaluate the landing surface best suited to handling the orbiter if the second tire fails. Evaluate techniques to help prevent the second tire on the strut from failing.

2) Study the effects of delays to the Multifunction Electronic Display System (MEDS) head down displays, due to receiving the variables driving the displays from a different data bus, on vehicle handling qualities.

3) Study the effect of an extended nose gear strut on the slapdown behavior of the orbiter.

4) Send upcoming crews and astronaut candidates through a crew familiarization matrix.

Simulation Results

Preliminary results of the tire failure study indicate that the surface with the best possibility of tire survival is the concrete, followed by the Northrop White Sands lakebed, and Edward's lakebed. During the study, another factor became important to the tire failure scenario. If one tire is "flat" at altitude, the remaining tire takes all of the load on the strut. If the load on the one remaining tire is above 155 klbs, the strut axle will begin to yield. If the load on the tire

Two issues studied in this simulation were tire failure prediction accuracy and Lake bed friction failure scenarios.

gets above 185 klbs, the strut axle will fail. A technique to help reduce the load on the failed tire side was developed. During the derotation, at approximately two to three degrees of pitch attitude, the pilot would input a roll command away from the blown tire side. This technique showed promise of reducing loads below the 155 klb yield threshold.

Preliminary results of theMultifunction Electronic Display System(MEDS) lag study indicate the lags are not noticeable when flying a nominal trajectory; however, if large inputs are made in an effort to detect the lags, delays can be seen by the pilot.

Preliminary results indicate that the extended nose gear strut was found to greatly reduce the maximum gear load on the main gear struts and no adverse rollout handling qualities were observed.

The crew familiarization phase of the simulation reinforced the importance of the VMS in preparing upcoming crews for the landing and rollout phase of the mission and for possible failures during that phase.

Investigative Team

NASA Ames Research Center
NASA Johnson Space Center
Rockwell International
Rockwell Space Operations Company

Variable Diameter Tiltrotor

Karen Studebaker, NASA ARC
Steven Belsley, Syre / Logicon

Summary

The Variable Diameter Tiltrotor (VDTR) is a Sikorsky Aircraft Corporation concept in which the rotors change diameter during flight in an attempt to optimize the performance characteristics of the rotor. The rotor operates at maximum diameter in helicopter mode and decreases in size during conversion to 66% diameter in airplane mode. This small diameter in airplane mode has the benefit of reduced tip speed for low noise and results in higher propulsive efficiency.

Introduction

In 1992, a wind tunnel test was conducted jointly by Sikorsky and NASA of a 1/6-scale VDTR rotor. The rotor was successfully converted between helicopter and airplane modes by remotely changing the rotor diameter and nacelle angle. Figure 2 shows the blade retraction mechanism from the test consisting of a jackscrew which moved an outer blade in and out over an inner torque tube to change diameter. This demonstrated the feasibility of the VDTR concept and motivated continued VDTR development including the current simulation activity to address the challenges of the Short Haul Civil Tiltrotor (SHCT)) Program.

The primary objective was to quantify the performance and handling quality characteristics of the VDTR to that of a fixed diameter tiltrotor CTR-8/96, for a SHCT mission. The test points will include steep approach procedures, terminal one engine inoperative (OEI) approach and departure procedures, and all engine inoperative procedures.

Related research includes ongoing VDTR activity such as vehicle sizing and economic analysis for the SHCT mission, proprotor aerodynamic design optimization, acoustic analysis, and planned isolated rotor and full-span wind tunnel tests at Ames and Langley tunnels.

Simulation Results

Preliminary results showed that both aircraft exhibited Level I, or satisfactory handling qualities during normal operations. However, for the more demanding tasks such as 9-degree instrument approaches, OEI operations and power-off autorotations, the VDTR exhibited superior performance and improved handling qualities.

For example, VDTR Category A type continued takeoff distances were typically 1/3 of that required by the fixed diameter tilt rotor, and rejected takeoff distances were reduced by about 1/2.

During Category A type landing procedures, the VDTR's ability to safely fly at lower airspeeds with one engine inoperative enabled it to be flown on a 9 degree glide slope to a lower decision height than the fixed diameter tilt rotor aircraft, resulting in a more comfortable approach and landing touchdown.

Evaluation pilots were universally enthusiastic about the performance improvements attributable to the VDTR's lower disk loading and higher rotor inertia. Pilot workload during power-off autorotations was significantly reduced with touchdown airspeeds as low as 25 knots; about half of that of the fixed diameter tilt rotor case.

Investgative Team

Boeing Aircraft Company
Federal Aviation Administration
NASA Ames Research Center
Sikorsky Aircraft
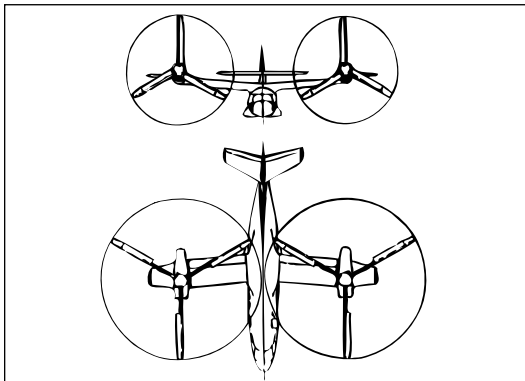
Figure 1. The VDTR shown airplane and helicopter modes.
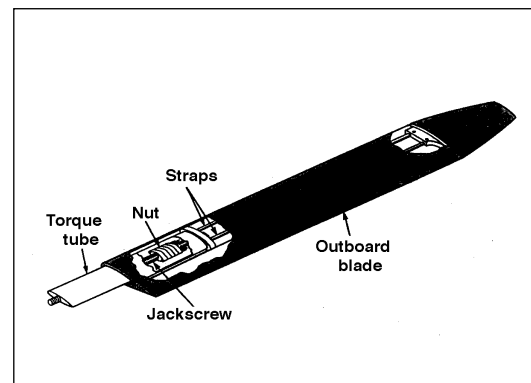
Figure 2. The VDTR blade used in the 1992 wind tunnel test.
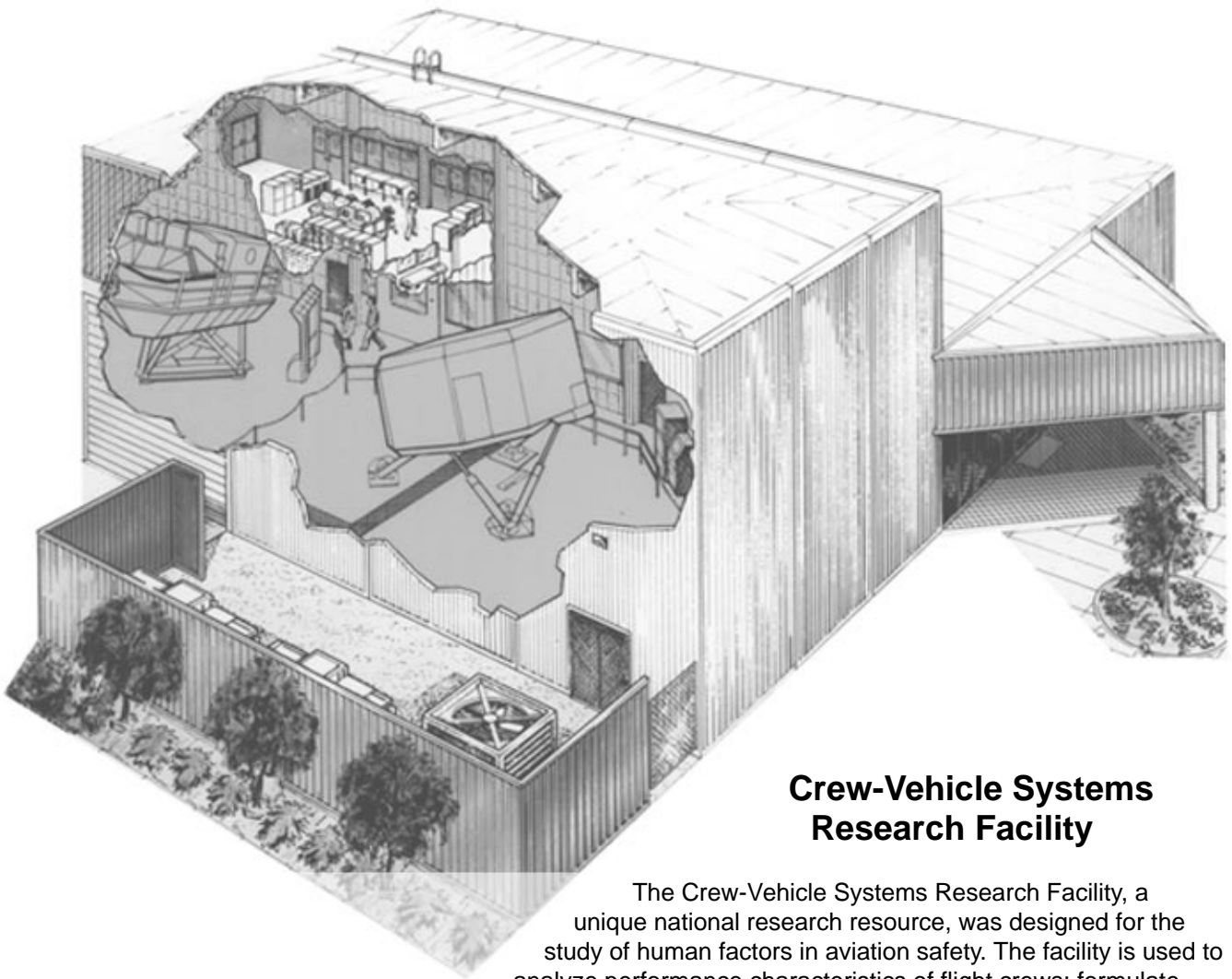
Crew-Vehicle Systems Research Facility

The Crew-Vehicle Systems Research Facility, a unique national research resource, was designed for the study of human factors in aviation safety. The facility is used to analyze performance characteristics of flight crews; formulate principles and design criteria for future aviation environments; evaluate new and contemporary air traffic control procedures; and develop new training and simulation techniques required by the continued technical evolution of flight systems.

Studies have shown that human error plays a part in 60 to 80 percent of all aviation accidents. The Crew-vehicle Systems Research Facility allows scientists to study how errors are made, as well as the effects of automation, advanced instrumentation, and other factors, such as fatigue, on human performance in aircraft. The facility includes two flight simulators-- a Boeing 747-400 and an Advanced Concepts Flight Simulator as well as a simulated Air Traffic Control System. Both flight simulators are capable of full-mission simulation.

Multiple Parallel Approaches Program

Summary

The simulation objective was to experiment with increased terminal area capacity without degrading safety. Evaluations were made of the feasibility of running dual parallel simultaneous runway operations, spaced 3000' apart, and employing a 2.50 degree localizer offset on one of the runways while using an advanced radar system.

Introduction

The Federal Aviation Administration Technical Center (FAATC) in Atlantic City, New Jersey, conducted a study to evaluate traffic handling capabilities and spacing requirements for running multiple parallel simultaneous instrument landing system approaches in instrument meteorological conditions. This experiment was the latest in a series of studies conducted in support of this program, whose overall mission was to try to increase terminal area capacity without degrading safety. Taking advantage of advanced radar systems such as the Precision Runway Monitor (PRM), this study was specifically designed to evaluate the feasibility of running dual parallel simultaneous runway operations, spaced 3000 apart, and employing a 2.50 degree localizer offset on one of the runways. The PRM utilizes a 1 second radar update sweep, as opposed to the conventional radar systems being used today which utilize a 4.8 second sweep, thus allowing more accurate tracking of traffic in the terminal area. The 747-400 simulator was one of several simulators throughout the country participating in this study and was connected to the FAATC's air traffic control simulation via a high speed digital voice/data communications system. Conditions for this study were developed in an effort to evaluate the viability of running dual simultaneous operations at New York's John F. Kennedys International Airport.

Simulation Results

To support this study, a fictitious airport database scene (KMPR) was created with dual parallel runways 18L and 18R. Scenarios for each of the runs began approximately 17 nautical miles out from the threshold. Upon release, participating subject pilots were instructed to land at one of two active runways. Occasionally, "blunder" aircraft were introduced into the scenario to see if the participating subject crews could safely perform missed approach maneuvers.

Real-time data depicting the 747 cab's position was transmitted back to the FAATC during experiment runs, as well as voice communications between the pilots in the simulator and the controllers back at the FAATC. Digital data, questionnaires and videotapes for each of the runs were collected during this study. One of the parameters measured in the study was the ability of the PRM system, which included controllers, pilots/aircraft, monitoring equipment and procedures to provide adequate separation in case of aircraft blunders. Whenever an aircraft strayed off course and entered the non-transgression zone it was considered a blunder. During the study, computers back at the FAATC recorded the percentage of time that 2 aircraft came within 500 feet of each other. When this happened, it was considered a Test Criteria Violation (TCV). Overall, ten 747-400 crews participated in this study, performing 227 runs. During these runs, 300 blunders were introduced without a single TCV. The results of this simulation helped provide the FAA with a new separation standard for parallel approaches.

Investigative Team

FAA Technical Center, Atlantic City
FAA Field Office, NASA Ames Research Center

Multiple Parallel Runway Study
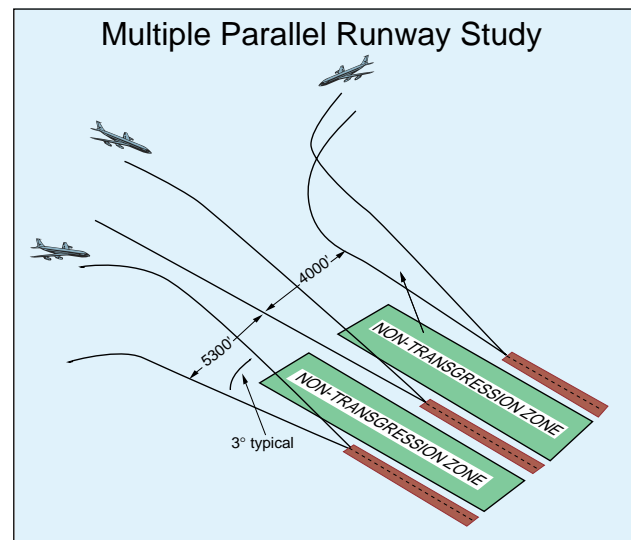
This simulation evaluated traffic handling capabilities and spacing requirements for running multiple parallel simultaneous instrument landing system.

Neuro Controlled Aircraft

Summary

Simulation objectives were to improve engine only performance through the use of neural networks and to evaluate blended control of all aircraft controls and engines concurrently.

Introduction

Several airline and military aircraft have crashed after having systems fail that cause partial or complete loss of control of the conventional control surfaces (rudder, aileron, elevator, flaps, slats) and aircraft engines. The Propulsion Controlled Aircraft (PCA) research program, performed on the ACFS in past years, developed good control for the case of complete flight control failure with no engine failure. The goals of the current experiment were to improve the performance of engine only control through the use of neural networks and evaluate a blended control of all aircraft controls and engines concurrently. The first goal, improved engine only performance, was achieved by implementing a learning neural net in place of the simple linear engine model used within the PCA control system. An algorithm was implemented for teaching the neural net in real-time as the pilot flies. This allowed the control system to automatically compensate for partial failures that degraded the engine performance.

The second goal used ninety-three possible control and engine failure combinations to evaluate the performance of the new control system . The PCA and Neuro Controlled Aircraft (NCA) simulation experiments support both the Ames Neural Net Laboratory research in the Information Sciences Directorate and the PCA Program at the Dryden Flight Research Center.

Simulation Results

NASA Ames and NASA Dryden test pilots flew both the neural net engine control system and the blended control system in a large matrix of failure
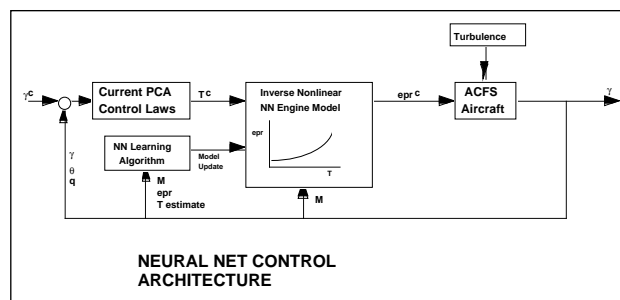
NEURAL NET CONTROL ARCHITECTURE

By implementing a learning neural net in place of the simple linear engine model used within the PCA control system, the control system was allowed to automatically compensate for partial failures that degraded the engine performance.

scenarios. The inverse nonlinear neural net engine model improved control of the aircraft as measured by reduced flight path angle and thrust excursions of nearly 20%. The learning neural net shows tremendous promise as a method to improve survivability in damaged aircraft. The blended control system provided pilots with a seamless transition and flight control mode regardless of failure type. Control surface failures were almost transparent to the pilot.

Future Plans

NCA-2 is scheduled for early 1997 and will expand the use of neural net control technology to the entire engine and flight control system. Additional investigations are under consideration using both neural net and fuzzy logic concepts as well as integration with different aircraft such as the C-17 military transport.

Investigative Team

CAELUM Company
NASA Ames Research Center

JFK Localizer Offset Approach Study

Summary
This experiment studied missed approach tracking data to determine safety and ease of operations under instrument flight rules.

Introduction
In support of the Multiple Parallel Approaches Program, the Federal Aviation Administration's (FAA's) Standards Development Branch in Oklahoma City conducted a study of missed approach tracking data used to determine the degree of safety and ease of operation of closely spaced parallel or near parallel approach and landing operations associated with operations conducted under instrument flight rules. The FAA was interested in evaluating the feasibility of using a 3 degree localizer offset approach to runway 22R at New York's John F. Kennedy International Airport. The current localizer offset at JFK's runway 22R is 2.5 degrees. The significance of the tracking data was to see if the pilots were able to avoid flying in the protected airspace of the adjacent runway 22L, which is spaced about 3000' apart from runway 22R.

Simulation Results
Scenarios consisted of approaches into JFK starting at about 17 miles out, which either resulted in a landing or missed approach. Pilots were given the option to fly the procedures either manually or through the autoflight system. Data collection consisted of videotapes, pilot questionnaires and digital recordings of relevant aircraft position and performance data. In addition, real-time data was being shipped back to Oklahoma City via modem during the experiment runs. Six days of data runs were completed, totaling 120 runs.

Investigative Team
FAA Standards Dev. Branch, Oklahoma City
FAA Field Office, NASA Ames Research Center

The FAA conducted a study to acquire missed approach tracking data for use in determining the degree of safety and landing operations.

Propulsion Controlled Aircraft

Summary
The use of a propulsion only flight control system was examined for situations where an airplane's primary flight control system became inoperative.

Introduction
The Information Systems Directorate conducted a study to examine the use of a propulsion only flight control system in an emergency situation where an airplane's primary flight control system became inoperative. The study utilized control laws developed at NASA Dryden to control aircraft flightpath angle by manipulating engine thrust to maintain pitch and roll control. This experiment was a continuation of previous work conducted in the Advanced Concepts Flight Simulator (ACFS) and the McDonnell-Douglas MD-11 aircraft at Long Beach. Unlike the earlier work on the ACFS, the primary focus was on the adaptability of the propulsion controlled aircraft (PCA) control laws to a four engine aircraft such as the 747-400 during approach and landing operations.

This study was primarily an engineering evaluation of the PCA concept for a four engine aircraft, and was evaluated for two different engine configurations. The first configuration used inboard engines for pitch and roll control, with the outboard engines left at idle. The second configuration utilized all four engines for pitch control, and just the inboard engines for roll control. This was necessitated by the 747's large asymmetric thrust moment arm, which made it too difficult to dampen out the resulting dutch roll characteristics when using the outboard engines for roll

control. To use the PCA system, pilots used the existing vertical speed and track knobs for maintaining pitch and heading control, respectively. Each of the participating pilots was asked to make various approaches with either conventional controls, with only one hydraulic system working (the 747-400 has 4 hydraulic systems), manually with throttles only, PCA coupled, with PCA localizer-only, and with the PCA mode control panel knobs only.

Simulation Results

Six days of runs were conducted with participating test pilots from NASA, Boeing and McDonnell-Douglas. Results from the study indicated that PCA performance was adequate at low altitudes in various approach configurations. However, the PCA control laws investigated need improvement at medium and higher altitudes. A follow-on study is in the plans to evaluate PCA over the entire flight envelope. This work is anticipated to be done early next fiscal year.

Investigative Team
NASA Ames Research Center
CAELUM Research Corp.
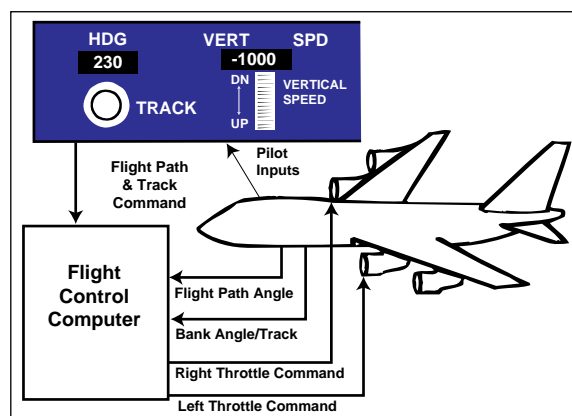
This simulation focused on the adaptability of the PCA control laws on a four engine aircraft during approach and landing operations.

Tracon-Flight Management System Trajectory Synthesis

Summary

Trajectories flown manually and with Flight Management System (FMS) procedures were compared to trajectories generated by TRACON Automation System developed at NASA Ames.

Introduction

The Air Traffic Management Branch conducted a study on the 747-400 Simulator to evaluate the precision of trajectories flown manually and with Flight Management System procedures, as compared to trajectories generated by the NASA Ames developed Center TRACON Automation System (CTAS). The Center TRACON Automation System is an automated air traffic control system designed to allow more efficient flight in the national airspace system while maintaining safety. This study was in support of one element of the Airspace Operations System Research Program. Other objectives of this study included examining the effect of FMS arrivals on pilot workload, communication and coordination, pilots heads down time, and the ability of pilots to fly the routes using the flight director.

Flight conditions consisted of approaches from two different eastern arrival gates, landing on runway 17L at Dallas-Fort Worth International Airport. In order to improve the accuracy of CTAS trajectories, quantitative flight path tracking data was collected and will be used to compare the method of computation of various maneuvers used in CTAS with the methods used by pilots, autopilots, and the FMS. A customized FMS database with specialized CTAS routings was developed and purchased from Honeywell in an effort to support this experiment.

Simulation Results

All of the test objectives were met for this study. Ten line-qualified 747-400 crews participated in this study, totaling 117 runs. Data collection consisted primarily of aircraft position and state data, videotapes and pilot questionnaires. Preliminary results indicated that the workload for entering route changes was very high and that flight director accuracy was deemed acceptable but invoked a high workload. It is believed that utilizing automation such as the data-link may reduce the increased pilot workload. The results will be studied further in the future.

Investigative Team
NASA Ames Research Center

3-D Audio for Traffic Alert & Collision Avoidance System

Summary

The use of 3-D Audio Signals for Traffic Alert and Collision Avoidance System (TCAS) alerts were studied by comparing target acquisition times under normal conditions to 3-D audio–assisted conditions and pilot preferences were evaluated for such a system.

Introduction

The flight path of a modern commercial transport aircraft often passes relatively close to many other aircraft. An on-board Traffic Alert and Collision Avoidance System evaluates the relative location and path of the other aircraft and determines if there is a risk of collision with the host aircraft. The relative location of the other aircraft is presented to the host aircraft crew on a navigational map display. In current aircraft cockpits, an aircraft that becomes a possible threat changes color on the display and a monaural voice warning is issued to the crew. After hearing the voice warning, the crew typically looks to the map display to get oriented, then looks out the window to locate the traffic.

It would be desirable to reduce the time it takes to locate a potential collision threat. This experiment studied the use of 3-Dimensional Audio Signals for TCAS alerts. Objectives were to compare target acquisition times for TCAS advisory-level intruding aircraft under normal conditions to 3-D audio–assisted conditions and to evaluate pilot preferences for such a system.

Each crew flew from San Francisco to Los Angeles twice, once with standard TCAS monaural warnings and once with the 3-D Audio warnings. During the flight they were presented with several hundred other aircraft (traffic) and 49 of these became actual collision threats which activated the warning system. The main parameter measured was the time it took for each crew to visually identify the threat following the warning message.
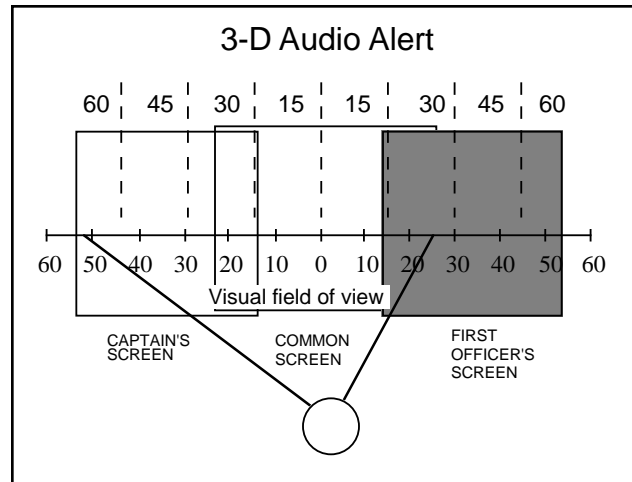
The horizontal field-of-view in the simulator, from the perspective of the left seat (Captain's position). The corresponding azimuth position of the 3-D sound cue is shown.

Simulation Results

Eleven two-person airline crews participated, including Boeing 737, 757, 747, and Airbus A320 pilots. The crews were able to visually locate the collision threat aircraft faster utilizing the 3-D Audio head up cueing system. Detailed results will be published in a reference journal with the data compared to results from similar 3-D Audio TCAS experiments that have been run on the ACFS since 1990. This was the last of three 3-D Audio studies performed on the ACFS. The published results may lead to implementation of 3-D Audio TCAS warning systems in commercial transports.

Investigative Team

NASA Ames Research Center
San Jose State University

Multiple Parallel Approaches II

Summary

The goal of this on-going program is to try to increase terminal area capacity without degrading safety by evaluating the feasibility of running triple parallel simultaneous runway operations.

Introduction

The FAA Technical Center (FAATC) in Atlantic City, New Jersey, conducted a study to evaluate traffic handling capabilities and spacing requirements for running multiple parallel simultaneous instrument landing system approaches in instrument meterological conditions. The goal of this on-going program is to try to increase terminal area capacity without degrading safety. Taking advantage of previous test work and advanced radar systems such as the Precision Runway Monitor (PRM), this experiment was designed to evaluate the feasibility of running triple parallel simultaneous runway operations. The PRM system employs a 1 second radar update sweep, as opposed to the 4.8 second sweep that is currently being used today, thus allowing more accurate tracking of air traffic in the terminal area.

The 747-400 simulator was one of several simulators throughout the country that participated in this study and was connected to the FAATC's air traffic control simulation via a high speed digital voice/data communications system. Conditions for this study were developed in an effort to evaluate the viability of running triple simultaneous operations at Atlanta's Hartfield and Pittsburgh's International Airports. A fictitious airport database scene (KMPR) was created with three parallel runways 18L, 18C and 18R. The separation distances between runways 18L and 18C was 5300 ft, and 4000 feet between runways 18C and 18R. Scenarios for each of the runs began approximately 20 nautical miles out and subject pilots were instructed to land at one of the three active runways. Occasionally, "blunder" aircraft were introduced into the scenario to see if the participating subject crews could safely perform missed approach maneuvers.

Simulation Results

This study was a follow-on study to a previous test conducted last fiscal year. Unlike the previous test, this study put a lot more emphasis on controller training and phraseology, as opposed to last year's test. Five 747-400 line-qualified crews participated in this study, performing 116 runs. Real-time data depicting the 747 cab's position was transmitted to the FAATC during experiment runs, as well as voice communications between pilots in the simulator and controllers back in Atlantic City. Digital data, questionnaires and videotapes for each of the runs were collected during this study.

Investigative Team

FAA Technical Center, Atlantic City
FAA Field Office, NASA Ames Research Center
NASA Ames Research Center
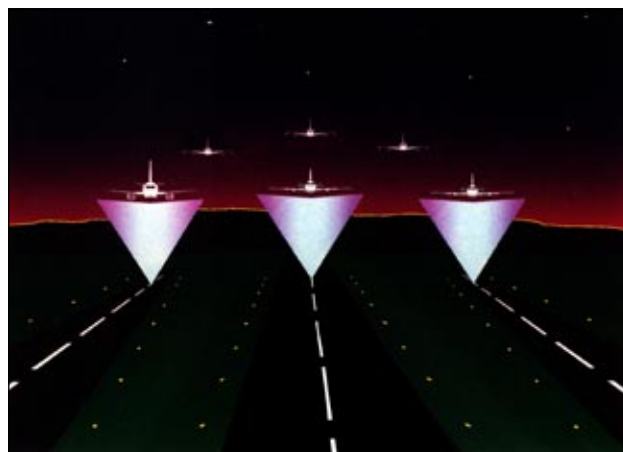
This study was designed to evaluate the feasibility of running triple parallel simultaneous runway operations, with runways spaced 4000 and 5300 feet, respectively.

Dynamic Aircraft Route Planning System

Summary

Air Traffic Control is in the process of developing, coordinating and issuing clearance for sending rerouted flight plan information to aircraft over the ocean. The goal of this experiment was to study timing issues regarding the issuance and integration of a revised flight plan from the standpoint of the flight deck.

Introduction

The FAA Technical Center (FAATC) in Atlantic City, New Jersey, conducted a study to examine the viability of sending rerouted flight plan information to aircraft over the ocean by exploiting the capabilities of emerging satellite-based communications, enhanced avionics capabilities, and advanced ground-based air traffic control and dispatch systems. The process by which this would be implemented is referred to as the Dynamic Aircraft Route Planning (DARP) System. The system is composed of the Traffic Management Unit (TMU), the Airline Operations Center (AOC) Flight Dispatch, Air Traffic Control (ATC), and the flight crew. Each is responsible for developing different aspects of the system: the TMU develops a new route based on the latest weather information; the AOC Dispatch develops a revised flight plan and then transmits it to the flight crew; ATC develops, coordinates, and issues the new route clearance; and the flight crew reviews and accepts the new flight plan and then requests a new route clearance from ATC.

The main objective was to focus primarily on timing issues regarding the issuance and integration of a revised flight plan from the standpoint of the flight deck. This system is heavily dependent on advanced technologies and capabilities such as those introduced by the Future Air Navigation System (FANS) upgrade conducted on the 747-400, and took full advantage of the recent FANS upgrade to the NASA 747-400 simulator. Four flight plans and corresponding wind profiles had to be pre-pro-
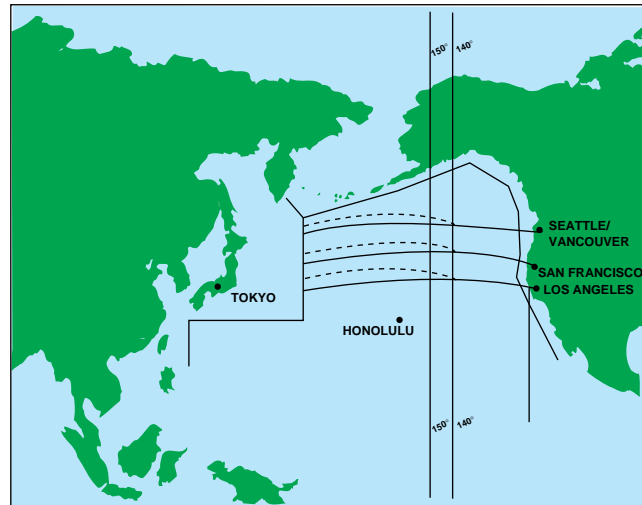
Illustration shows alternative flight paths (dashed line) taken when pilots are dispatched information about planned flight path weather conditions.

grammed so they could be transmitted to the 747 cab via the newly created AOC and ATC data-link control pages on the Experimenter Operator Station (EOS). This information had to be processed in the proper character and bit oriented protocols for the AOC and ATC data-link messages, respectively. Participating 747-400 flight crews flew various oceanic routes which were then rerouted through the DARP process.

Simulation Results

This study was completed successfully with excellent reviews from the FAA principal investigators, and proved to be an excellent shakedown of the recent FANS implementation.

Investigative Team

FAA Technical Center, Atlantic City
FAA Field Office, NASA Ames Research Center
NASA Ames Research Center

Center TRACON Automation System, Descent Advisories

Summary

The Center TRACON Automation System (CTAS) is an automated air traffic control system designed to allow more efficient flight in the national airspace system while maintaining safety. This experiment evaluated the use of CTAS descent advisory clearances, procedures and pilot briefing materials and documented how crew performance changes with repetitive experience in flying the CTAS DA procedures.

Introduction

In support of the Terminal Area Productivity (TAP) program the Aviation Operations Branch in the Flight Management & Human Factors Division conducted a study that examined issues associated with automated air traffic control and its impact upon flight crews' ability to use aircraft automation. The Center TRACON Automation System (CTAS) is an automated air traffic control system designed to allow more efficient flight in the national airspace system while maintaining safety. An essential element of CTAS, the Descent Advisor (DA), provides an estimate of when an aircraft arrives at a specific waypoint on the approach path and is intended to help the controller sequence aircraft efficiently for landing. The success of this prediction depends in part on how accurately pilots fly the descent, and has required the development of special clearances and a special descent procedure. One problem discovered during the Field Trial conducted in the fall of 1995 was the difficulty pilots and controllers had working with the lengthy clearances used to convey the CTAS descent information. Objectives were to evaluate the use of CTAS Descent Advisory clearances, procedures and pilot briefing materials; explore how the ARINC Communications Reporting and Addressing System (ACARS) and Future Navigation System (FANS-1) datalink capabilities on the 747-400 simulator could be used to support CTAS descents; and to document how crew performance changes with repetitive experience in flying the CTAS DA procedures.

Simulation Results

Nine line-qualified 747-400 airline crews flew a series of descents into Denver. Each flight began near Meeker (EKR) at a cruise altitude of 33,000 feet with a nominal cruise speed of Mach 0.82. All crews received a "Jeppesen" plate describing the performance requirements for the "Precision Descent" procedure. Half of the crews also received a Flight Manual Bulletin describing a specific technique for accomplishing the procedure using the aircraft's Flight Management System (FMS). In order to simulate conditions "on the line," no feedback was provided to the pilots if they misinterpreted an aspect of the procedure. Preliminary results indicate that the crews that received the Flight Manual Bulletin had less trouble interpreting the procedure and made fewer violations of the performance requirements of the Precision Descent procedure.

To test the use of ACARS and FANS datalink capabilities on the 747-400 simulator, pilots received an ACARS datalink message to expect a precision descent about 10 minutes before the top of descent. This ACARS message included the expected descent speed and the expected CTAS assigned descent point. Preliminary results indicate that this message allowed pilots plenty of time to program their FMS computer for the descent and was successful in removing any time pressure from the procedure. On the last descent of each day's runs, pilots received a FANS-1 "route clearance." This route clearance consisted of the waypoints from the arrival routing. The vertical descent profile was defined by including altitude and speed crossing restrictions on four of the waypoints. Preliminary results indicate a number of problems with current FMS' and current airline operating procedures. For example: 1) Only waypoints in the aircraft's nav database can be used in route clearances. This made it difficult to define the vertical path. 2) All speed constraints at waypoints are treated as "at or below" constraints, making it impossible to specify a descent speed faster than the speed that has been entered on the vertical navigational approach Descent page. 3) The procedures of one airline require the pilots to set the mode control panel altitude to the most constraining altitude. This makes flying a descent composed of a series of altitude restrictions a high workload task requiring vigilance and carefully timed inputs to the autoflight system to insure a smooth descent.

Investigative Team

NASA Ames Research Center
San Jose State University
Sterling Software

Barometric Vertical Navigation

Summary

Simulation objectives included collecting and analyzing pilot Flight Technical Error data obtained when flying various vertical navigation (VNAV) scenarios, investigating Flight Management System (FMS) operational modes, and examining any unique procedural design or charting rules needed to accommodate barometric VNAV approaches.

Introduction

The Federal Aviation Administration's (FAA) Standards Development Branch in Oklahoma City, Oklahoma, conducted a study to evaluate the use of lateral/vertical navigation approaches (LNAV/VNAV) using the Flight Management System. The FAA and the Secretary of the Transportation Safety Initiative feel that there is a need for a stabilized final approach during nonprecision approaches, which has also been recognized by the International Civil Aeronautics Organization, Controlled Flight Into Terrain Task Force. Both agree that flight path angles on nonprecision approaches should be based on a nominal 3 degree angle. This is to allow for a stabilized approach much like that flown on an instrument landing system approach. Other objectives included examining FMS operational modes and any unique procedural design or charting rules necessary to perform a VNAV approach.

In addition to the safety benefits of a stabilized approach, lower approach minimums may be possible due to the application of a suitable sloping obstacle clearance assessment surface instead of a constant Required Obstruction Clearance value applied over the entire final approach obstacle clearance area. Since modern aircraft such as the 747-400 are equipped with flight management systems capable of computing barometric VNAV paths and providing deviations from there, it is believed that a suitable sloping obstacle assessment surface for FMS equipped aircraft with barometric VNAV capability can be developed.

To support this study, a customized FMS navigational database was created by Honeywell at the request of the FAA to enable participating subject pilots to fly the specialized procedures taking advantage of the FMS provided LNAV/VNAV capabilities. Scenarios were developed for approaches into New Jersey's Atlantic City International Airport, and Bradley International Airport in Windsor Locks, Connecticut.

Simulation Results

Participating pilots flew a series of manual approaches using the flight director with LNAV/VNAV guidance from the FMS. Overall, ten days of runs were completed for this study, using 19 line qualified 747-400 pilots, totalling 155 runs. Pilot Flight Technical Error (FTE) data was collected and analyzed when flying various VNAV scenarios. The FTE data will be used in conjunction with other data to determine the FTE component of barometric VNAV Total System Error. Particular attention was paid to mode transitions and the possible impact on obstacle clearance criteria as well as pilot acceptability and flyability.

Investigative Team

FAA Standards Development Branch, Oklahoma City

FAA Field Office, NASA Ames Research Center

NASA Ames Research Center

The FAA evaluated the use of of lateral/ vertical approaches using the Flight Management System.

Advanced Air Transportation Technologies Free Flight

Summary

Two new features were developed and integrated as part of the simulation: a new alerting scheme logic and the "Route Assessment Tool" .

Introduction

The Aviation Operations and Flight Deck Branches in the Flight Management & Human Factors Division and the Massachusetts Institute of Technology (MIT) collaborated in a study to evaluate the "alert" and "protected" zone airspace definitions for free flight, and to investigate pilots' interpretation of Visual Flight Rules right of way procedures and their application to the free flight environment. In the free flight environment, aircraft will presumably be able to maneuver with more autonomy. However, free flight will require the definition of new zones around each aircraft, similar to the zones currently provided by the Traffic Alerting and Collision Avoidance System (TCAS) alert algorithms. These zones will be defined as the alert and protected zones. Roles and responsibilities associated with the transgression of these zones need to be defined and evaluated.

A new alerting scheme logic was developed by MIT and integrated as part of the simulation. This logic defined "alert" and "protected" zones around the ownship of an aircraft and provided intruder information up to 100 miles beyond the currently used TCAS zones. The "alert" zone is defined by a complex algorithm based on the spatial geometry between an aircraft's ownship position and that of an intruder, the probabilities of a conflict, and the ability to maneuver out of the conflict. The "protected" zone, inside the alert zone is defined as the separation distance of five miles between two aircraft. In order to make the flight crew aware of their situation with respect to other aircraft, new symbology was developed and integrated on the flight crew's navigation displays. Whenever an intruder penetrated the alert zone a prediction line extended from the ownship's position to the point of closest approach on it's route, as well as a prediction line on the intruder aircraft which penetrated the alert zone to the point of closest approach on the intruder's route. At that time an aural warning - "Alert Zone Transgression" was triggered to alert the ownship's flight crew.
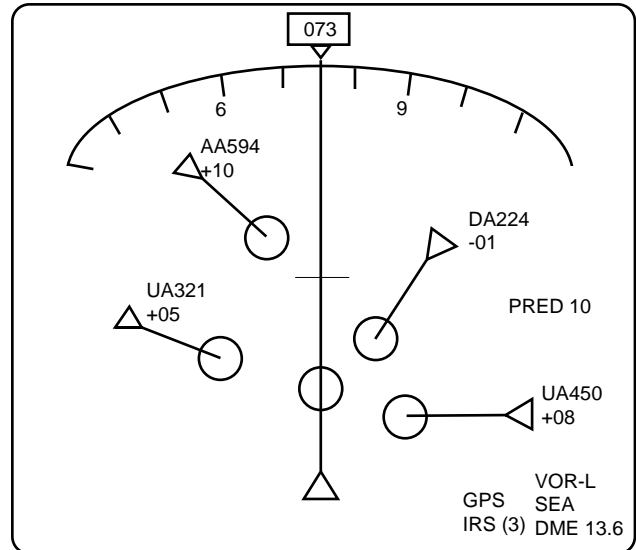
Figure shows the AATT navigation display modifications, the apex of triangle indicates position.

An additional feature used the "Route Assessment Tool" which enabled pilots to select "what if?" features to avoid encounters with other aircraft. This tool enabled pilots to select variations in ownship speed, heading or altitude allowing pilots to look at possible avoidance maneuvers ten minutes ahead of time. A customized control panel was constructed and integrated in the 747 cab to support this capability.

Simulation Results

Experiment runs consisted of several enroute scenarios flown in the Denver airspace. The scenarios involved the 747 simulator and other pseudo-aircraft generated by the CVSRF's Air Traffic Control Simulator. Depending on the threat levels of the pseudo-aircraft, subjects were required to negotiate with the other aircraft and execute an avoidance maneuver.

Investigative Team
NASA Ames Research Center

Advanced Simulator Network

The Advanced Simulator Network Project is an integration of newer and higher-performance host computers and real-time data acquisition networks into the VMS complex. The system provides significantly better performance while retaining the powerful functionality of the current system. The integration of the new system was completed in FY96.

The overall project had two separate phases: a prototype phase and an integration phase. The prototype phase, consisting of proving the design through the acquisition, integration and successful testing of a prototype system, was the primary focus during FY94-95. The prototype system hardware was acquired and the simulation executive software from the currently used hosts was ported to a Digital Equipment Corp. ALPHA AXP 1000 4/233 host. Tests of the prototype system confirmed that the performance expectations could be met and that the functionality of the current system was carried over.

The performance increase of the operational systems is dramatic. By themselves the computers are twice as fast as the computers bought just four to five years ago. Testing of the new CAMAC instrumentation shows a ten times speed-up in performance over the old hardware. Both improvements are important as time delays can cause a simulated aircraft to lose stability in comparison to the real aircraft. For designs for which there is no real aircraft for comparison, incorrect conclusions can be made when the simulator uses poor equipment and/or techniques. The VMS system is capable of frametimes of less than one millisecond when only I/O is performed with the motion, laboratory and cockpit sub-systems. Adding the typical aircraft model allows frametimes as small as five milliseconds. As a practical matter, most simulations are run at longer frame times more compatible with the sixteen 2/3 millisecond field time of the associated graphics generators. However, the ASN system allows performance options heretofore unavailable.

Early in FY96, the first of the systems was installed into an Interchangeable Cab fixed base simulation laboratory. After exhaustive testing and rework, the ASN system was sufficiently perfected to put it into the Vertical Motion Simulator itself. Before the end of FY96, the VMS system had been used by five simulations. The last of the three labs was successfully completed in September 1996.

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Logicon / Syscon	

The performance increase of the operational systems is dramatic. By themselves the computers are twice as fast as the computers bought just 4-5 years ago. Testing of the new CAMAC instrumentation shows a 10 times speed-up in performance over the old hardware.

Simulation Fidelity Requirements

The Simulation Fidelity Requirements simulation was an effort by NASA Ames Research Center to determine required cueing fidelities for motion-based flight simulation operations. The first focus was to establish quantitative criteria and specifications for visual and motion systems characteristics in roll-lateral cross-coupled axes with respect to the simulated aircraft's characteristics and tasks. Investigations were to determine the required performance of each individual cueing device and how close they have to be synchronized without effecting perceived overall response.

A two degree-of-freedom representative rotorcraft model was developed with a satisfactory rate command response characteristics. A frequency response approach was applied extensively to set up the Vertical Motion Simulator's visual and motion cueing response. The motion system was also configured for one-to-one response such that artifacts from using washout could be completely eliminated. The Army's ADS-33D and FAA AC 120-63 were used as references to tune the rotorcraft model response and motion system response respectively. An array of cueing delays were added randomly to the visual and motion system to examine system throughput delay effects in a range from 45 msec to 125 msec.

Simulation Results

A total over one thousand runs were made with seven pilots from FAA, Lockheed Martin, NAWCAD, NASA Langley, and Ames. Pilot handling qualities ratings, motion fidelity ratings, cueing fidelity ratings, power spectrum density of the control stick, and statistical data on pilot performance were analyzed. Preliminary results suggests that a mismatch among visual, roll motion, and lateral motion that is greater than forty msec has significant effects on pilot work load and the overall perceived motion fidelity.

In a study of motion versus no-motion, i.e. fixed base, pilots all performed the 20-ft sidestep task well with synchronized visual and motion configuration. All pilots performed poorly initially with no motion. They could eventually adapted to no-motion and achieved desired performance only after they changed their strategy to do the task. In those cases, test results showed greater control activities and more overshoots in their station keeping performance.

Three pilots also went through another study to investigate required roll-lateral motion cues in a coordinated maneuver. The data suggests new boundaries for roll motion gains and roll-lateral coordination gains for desired and adequate performance.

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An effort by NASA Ames Research Center was made to determine required cueing fidelities for motion-based flight simulation operations.

Future Air Navigation System

An advanced avionics system upgrade incorporating new capabilities was added to the 747-400 simulator this past year. This advanced Future Air Navigation System (FANS) will utilize global satellite information and advanced digital communications for providing the communications, navigation, surveillance and air traffic management for all regions of the world for the twenty-first century. Through the efforts of the International Civil Aviation Organization, the International Air Transport Association (IATA), and other air traffic service providers, this system is envisioned to transition the current air traffic control system to an advanced air traffic management system by the year 2010. The relative importance of integrating FANS in the NASA 747-400 simulator is that it enables the CVSRF to support important national research programs such as NASA's Advanced Air Transportation Technologies (AATT) Program and the Federal Aviation Administration's Dynamic Aircraft Route Planning (DARP) and Free Flight Programs.

The FANS modification was primarily a Boeing-Honeywell implementation to upgrade the 747-400 simulator with FANS compliant avionics. Integral to this upgrade, satellite navigation and communications systems were implemented by creating a Global Positioning System (GPS) simulation including emulating all of the required sensor signals going to the Flight Management Computer's (FMC's), and a satellite based communications (SATCOM) system providing a more reliable voice and data-link capability than which currently exists today. Other FANS modifications to the simulator included upgrades to the various installed avionics, specifically the two FMC's, the three Multi-function Control Display Units (MCDU's), the Multi-input Cockpit Printer and the ARINC Communications, Addressing and Reporting System's (ACARS) Management Unit. Also, there were modifications to the 747-400's Engine Indication and Crew Alerting System (EICAS) displays, the Modular Avionics and Warning Electronics Assembly (MAWEA) system for pending data-link messages, and the 747's navigation displays depicting the use of GPS data for primary navigation.

Other key features of the FANS upgrade included Automatic Dependent Surveillance (ADS) which
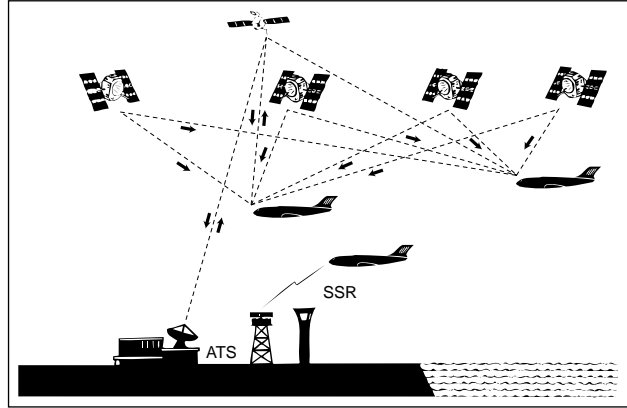
The Future Air Navigation System (FANS) utilizes global satellite information and digital communications to provide communications, navigation, surveillance and air traffic management to all regions of the world.

allows more precise aircraft tracking, an Airline Operational Communications Data-Link (AOC DL) capability for transmitting flight plan information, winds forecast data and route modifications, and an Air Traffic Control Data-Link (ATC DL) capability for transmitting air-ground messages including clearance uplinks. The interfaces for these features were provided via specially designed control pages on the 747 simulator's Experimenter Operator Station's (EOS). The EOS incorporates a customized graphical user interface consisting of input buttons, menus, display windows, etc., which can be programmed to emulate the behavior of a typical controller workstation. All data-link applications consist of airborne and ground-based counterparts which exchange data through specially formatted messages and are transmitted via an ACARS network. The airborne side of these applications were included as part of the upgraded avionics. Extensive development was required to create the new ground based features. Malfunction selection pages, an integral feature of the EOS, were also upgraded to provide the capability to input specific malfunctions to the FANS related systems, emulating system failures or anomalies. In addition to the data-link applications discussed above, some additional features were included as part of the upgraded FMC avionics. These features

**Note: Circles - Simulated Components
Rectangles - Installed Avionics**
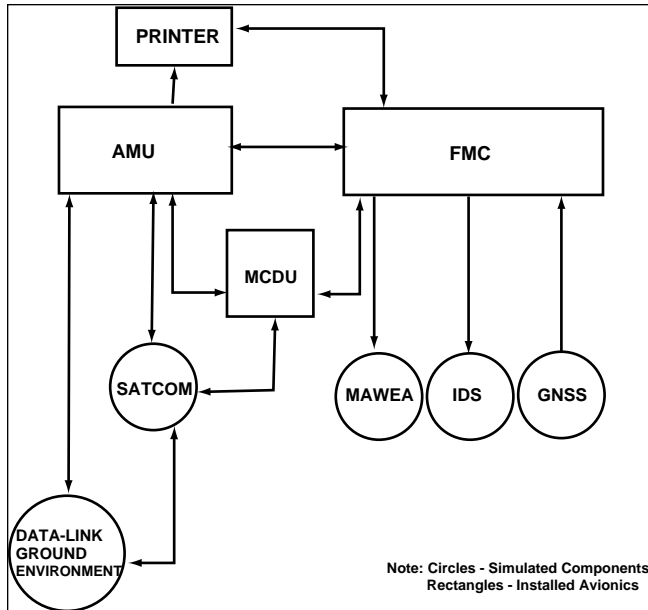
The two Flight Management Computers (FMC), the three Multifunction Control Display Units (MCDU), the Multi-input Cockpit Printer and the ARINC Communications and Reporting System (ACRS) are affected by FANS

included Required Time of Arrival (RTA) utilizing time based navigation, and Required Navigation Performance (RNP) which compares actual position versus required position on a given route.

Other benefits provided by FANS include the ability for pilots to automatically load up-linked flight plan changes into the FMC without having to manually type in the revised information, providing a more efficient means of accepting clearances than what is used today. With the introduction of ADS, and the ability to up-link an optimal flight plan based on the latest weather information, reduced separation of aircraft for FANS equipped aircraft is possible, thereby increasing efficiency and savings in fuel costs for air carriers. These features provided by FANS are the first step in transitioning the current air traffic control system to a more efficient and safer air traffic management system. Incorporating FANS into the NASA 747-400 simulator enables NASA to examine human factors and airspace operational issues such as the automatic information transfer of flight plan changes or other ATC information, not just in the oceanic arena, but eventually in the terminal area as well, providing a safer overall flying environment.

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NSI Technology Services Corp.

ACFS UPGRADE PHASE 2

The ACFS Upgrade Project goal is to ensure the simulator remains capable of supporting NASA mission critical research in the areas of aeronautical human factors, aviation safety, and airspace operations. Phase 1 of the ACFS Upgrade Project was completed last year and comprised the upgrade of many of the simulator computational systems, specifically the host computer, Experimenter Operator Station computers, and the data communication systems and flight display computers. Phase 2 of the ACFS Upgrade Project was substantially completed this year. The goal of phase 2 was to rebuild the cockpit with new high performance systems. This included the construction of a new cockpit, including elaborate auto-throttle system, new flight displays, and new aural cueing system. The specific goal was to achieve a current glass cockpit architecture with much higher performance pilot cueing devices that are flexible, reliable, and inexpensive to maintain.

Results

The new aural cue generator was installed concurrently with experiment development in January 1996 and used for the 3D Audio for TCAS experiment. In May, the cockpit was completely disassembled and a new center console, instrument panel, side consoles, and throttle system were constructed. The new instrument panel includes ergonomic locations for the primary pilot controls and provides a good replication of typical modern commercial flight deck layouts. A set of 8 new flight displays were specified, procurement initiated, and the software modified to the new size and format. The new flight displays will provide separate display computers for each display (previously one computer was used to drive two displays). This allows a new research display to be developed off-line then installed and run with very low integration effort since there is no longer a need to integrate the new software with existing software for the other display. The new displays will be installed in December of 1996 and will provide very high quality image presentation and greatly improved reliability. The new throttle system was installed and tested in September and provides a very realistic control interface and high performance back-drive capabilities. The completed cockpit will provide a reliable state of the art environment for future NASA airspace operations research.

Plans:

Phase 2 will be completed in January of 1997. The final stage of this effort, Phase 3, includes a new Out-The-Window visual system, Input/Output system, and a Head Up Display . These systems will be installed in the second and third quarter of FY97. An additional effort is currently underway to significantly enhance the Flight Management System. This effort includes a team comprised of personnel from both the Aeronautical Test and Simulation Division and the Flight Management and Human Factors Division.

Simulation Support Team

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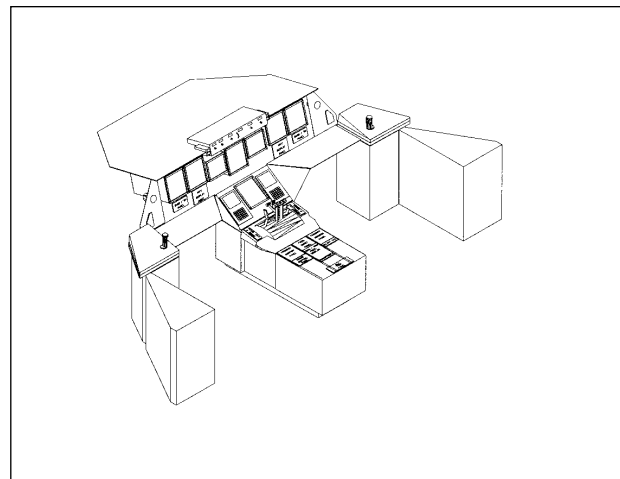
The ACFS simulator was upgraded to continue its support of NASA's mission critical research in the areas of aeronautical human factors, aviation safety, and airspace operations.

AATT .... Advanced Air Transportation Technologies
ACAH .... Attitude Command, Attitude Hold
ACARS .... ARINC Communications & Reporting System
ACFS .... Advanced Concepts Flight Simulator
ADS .... Automatic Dependent Surveillance
AGL .... Above Grouund Level
ANOE .... Automated Nap-Of-the-Earth
AOC DL .... Airline Operational Communications Data-Link
AO Div .... Aeronautical Test & Simulation Division
ASN .... Advanced Simulator Network
ASTOVL .... Advanced Short Takeoff & Vertical Landing
ATC .... Air Traffic Control
BAC .... Boeing Aircraft Company
BHT .... Bell Helicopter Textron
British CAA .... British Civilian Aviation Authority (regulatory agency)
CAE .... Canadian Aeronautics & Electronics
CATAPOD .... Category A Terminal Area Procedures
CFIT .... Controlled Flight Into Terrain
LNAV .... Lateral Navigation
c.g. .... center of gravity
CTAS .... Center TRACON Automation System
CTR .... Civil Tilt Rotor
CVSRF .... Crew-Vehicle Systems Research Facility
DA .... Descent Advisor
DARP .... Dynamic Aircraft Route Planning
DOF (6) .... Six Degree-Of-Freedom
DVE .... Degraded Visual Environment
EICAS .... Engine Indication and Crew Alerting System
EOS .... Experiment Operator Station
ESIG-3000 .... Evans & Sutherland Image Generator- 3000
FAA .... Federal Aviation Administration
FANS .... Future Air Navigation System
FCS .... Flight Control System
FMC .... Flight Management Computers
FMS .... Flight Management System
FTE .... Flight Technical Error
GFC .... Guidance Flight Control
GNSSU .... Global Navigation Satellite Sensor Unit
GPS .... Global Positioning System
GTRS .... Generic Tilt Rotor System
HDD .... Head-Down Display
HelMEE .... Helicopter Maneuver Envelope Enhancement
HSCT .... High Speed Civil Transport
HSR .... High Speed Research
HUD .... Head-Up Display
IATA .... International Air Transport Association
IBM .... International Business Machines
IC .... Initial Conditions
ICAB .... Interchangeable Cab
ICAO .... International Civil Aeronautics Organization
IHADSS .... Integrated Helmet Display and Sighting System
ILS/MLS .... Instrument Landing System/Microwave Landing System

IMC .... Instrument Meteorological Conditions
I/O .... Input/ output
IQS .... International Qualification Standard
KSC .... Kennedey Space Center
LNAV .... Lateral Navigation
MAWEA .... Modular Avionics and Warning Electronics Assembly
MCDU .... Multifunctional Control Display Unit
MCP .... Mode Control Panel
MDA .... McDonnell Douglas Aircraft
MEDS .... Multifunction Electronic Display System
MIDI .... Musical Instrument Digital Interface
MIT .... Massachusettes Institute of Technology
NASA .... National Aeronautics & Space Administration
NCA .... Neuro Controlled Aircraft
NOE .... Nap-of-the-earth
NVG .... Night Vision Goggles
OEI .... One Engine Inoperative
PCA .... Propulsion Controlled Aircraft
PDG .... Pilot Directed Guidance
PDGTRS .... Preliminary Design Generic Tiltrotor Simulation
PIO .... Pilot-Induced Oscillation
PRM .... Precision Runway Monitor
R-cab .... Rotorcraft Cab
RC .... Rate Command
RNP .... Required Navigation Performance
RTA .... Required Time of Arrival
RTF .... Return To Flight
S-cab .... Space Shuttle (interchangeable) Cab
SATCOM .... Satellite-basedCommunications
SCAS .... Stability & Control Augmentation System
SFO.. San Francisco International Airport
SHCT .... Short Haul Civil Tiltrotor
SimLab .... Simulation Laboratories (part of the AO Division)
SSV .... Space Shuttle Vehicle
STA .... Shuttle Training Aircraft
STOVL .... Short TakeOff and Vertical Landing
TAEM .... Terminal Area Energy Management
TAP .... Terminal Area Productivity
TCAS .... Traffic Alerting and Collision Avoidance System
TERPS .... Terminal Procedures
TIFS .... Total In-Flight Simulator
TRACON .... Terminal Radar Control
TRC.. Translational Rate Command
VFR .... Visual Flight Rules
VMS .... Vertical Motion Simulator
VNAV .... Vertical Navigation
XV-15 .... Experimental Vehicle 15, a tiltrotor

A very brief description of the Aeronautical Test and Simulation Division facilities follows. More detailed information can be found on the world wide web at: http://www.simlabs.arc.nasa.gov

Boeing 747-400 Simulator

This simulator represents a cockpit of one of the most sophisticated airplanes flying today. The simulator is equipped with programmable flight displays that can be easily modified to create displays aimed at enhancing flight crew situational awareness and thus improving systems safety. The simulator also has a fully digital control loading system, a six degree-of-freedom motion system, a digital sound and aural cues system and a fully integrated autoflight system which provides aircraft guidance and control. It is also equipped with a weather radar system simulation. The visual display system is a Flight Safety International driven by a VITAL VIIe. The host computer driving the simulator is one of the IBM 6000 series of computers utilizing IBM's reduced instruction set computer (RISC) Technology. An additional IBM 6000 computer is provided solely for the purpose of collecting and storing data in support of experiment studies.

The 747-400 simulator provides all modes of airplane operation from cockpit preflight to parking and shutdown at destination. The simulator flight crew compartment is a fully detailed replica of a current airline cockpit. All instruments, controls and switches operate as they do in the aircraft. All functional systems of the aircraft are simulated in accordance with aircraft data. To ensure simulator fidelity the 747-400 simulator is maintained to the highest possible level of certification for airplane simulators as established by the Federal Aviation Administration (FAA). This ensures credibility of the results of research programs conducted in the simulator.

Advanced Concepts Flight Simulator

This unique research tool simulates a generic commercial transport aircraft employing many advanced flight systems as well as features existing in the newest aircraft being built today. The ACFS generic aircraft was formulated and sized on the basis of projected user needs beyond the year 2000. Among its advanced flight systems, the ACFS includes touch sensitive electronic checklists, advanced graphical flight displays, aircraft systems schematics, a flight management system, and a spatialized aural warning and communications system. In addition, the ACFS utilizes side stick controllers for aircraft control in the pitch and roll axes. ACFS is mounted atop a six degree-of-freedom motion system.

The ACFS utilizes SGI computers for the host system as well as graphical flight displays. The ACFS are visual generation and presentation systems and are the same as the 747-400. These scenes depict specific airports and their surroundings as viewed at dusk, twilight, or night from the cockpit.

Air Traffic Control Simulator

The Air Traffic Control (ATC) environment is a significant contributor to pilot workload and, therefore, to the performance of crews in flight. Full-mission simulation is greatly affected by the realism with which the ATC environment is modeled. From the crew's standpoint, this environment consists of dynamically changing verbal or data-link messages, some addressed to or generated by other aircraft flying in the immediate vicinity.

The CVSRF ATC simulator is capable of operating in three modes: stand-alone, without participation by the rest of the facility; single-cab mode, with either advanced or conventional cab participating in the study; and dual-cab mode, with both cabs participating.

Vertical Motion Simulator Complex

The VMS is a critical national resource supporting the country's most sophisticated aerospace R&D programs. The VMS complex offers three laboratories fully capable of supporting research. The dynamic and flexible research environment lends itself readily to simulation studies involving controls, guidance, displays, automation, handling qualities, flight deck systems, and accident/incident investigations. Other areas of research include the development of new techniques and technologies for simulation and defining requirements for training and research simulators.

The VMS' large amplitude motion system is capable of 60 feet of vertical travel and 40 feet of lateral or longitudinal travel. It has six independent degrees of freedom and is capable of maximum performance in all axes simultaneously. Motion base operational efficiency is enhanced by the interchangeable cab (ICAB) system. Each of the four simulation cockpits is customized, configured and tested at a fixed-base development station and then either used in place for a fixed base simulation or moved on to the motion platform.

Digital image generators provide full color daylight scenes and include 6 channels, multiple eye points, and a chase plane point of view. The VMS simulation lab maintains a large inventory of customizable visual scenes with a unique in-house capability to design, develop and modify these databases. Real-time aircraft status information can be displayed to both pilot and researcher through a wide variety of analog instruments, and Head-Up, Head-Down or Helmet-Mounted Displays.

For additional information, please contact

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